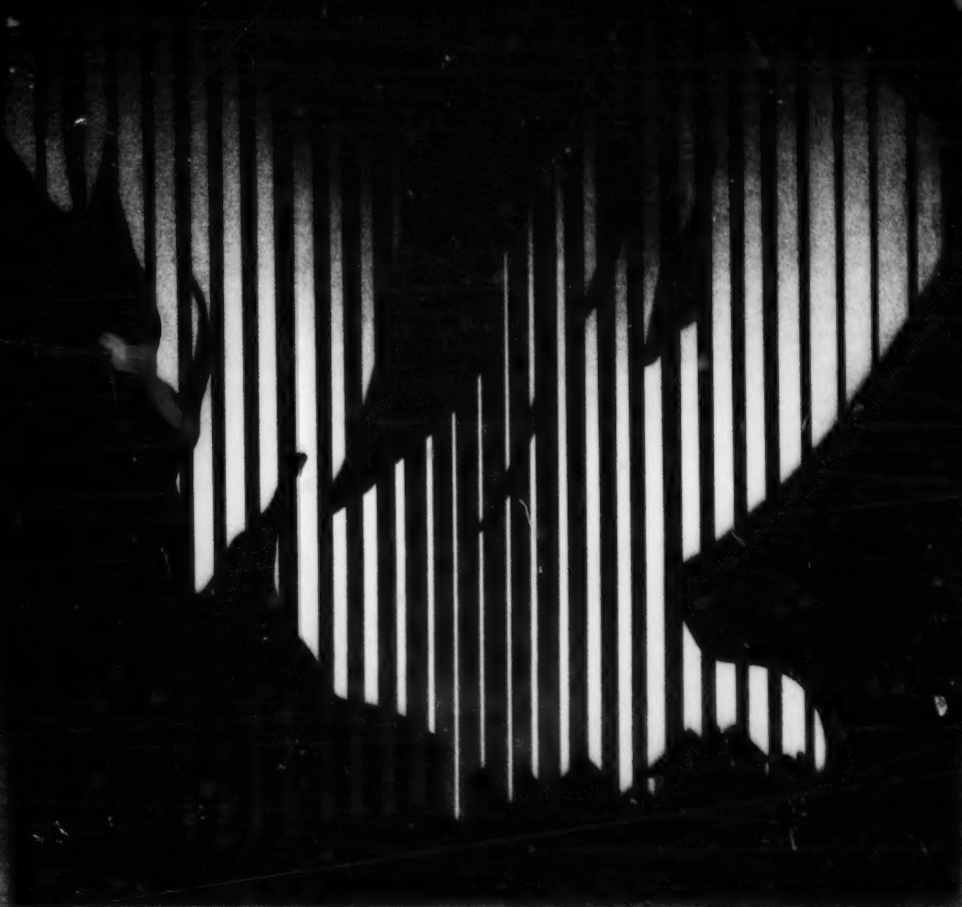

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

WHITEHORSE
EFFICIENT
WOODHEAT
DEMONSTRATION

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EXECUTIVE SUMMARY

I. BACKGROUND AND OBJECTIVES

A significant body of laboratory test data has demonstrated that new woodheat technologies can significantly reduce smoke emissions and improve overall efficiency. In an effort to determine the effectiveness of the new technologies under "in-home" conditions, the City of Whitehorse, supported by Energy, Mines and Resources Canada and the Government of the Yukon, secured funding under the Remote Community Demonstration Program and the Canadian Combustion Research Laboratory, both of Energy, Mines and Resources Canada, to conduct a demonstration of the performance of the new residential woodheat technologies.

The woodheat technologies demonstrated in the study had not been evaluated under "in-home" conditions. A general goal of this study was to reach meaningful conclusions regarding the effectiveness of new woodheat technologies at:

1. Reducing the impact of residential woodheat emissions on ambient air quality.
2. Reducing the risk associated with chimney fires and safety of operation in the home.
3. Improving the energy efficiency of residential woodheating.

The study was specifically designed to achieve the following objectives:

1. Quantify the emission characteristics of both conventional and new residential woodheat technologies (integral catalytic woodstoves, catalytic "add-on" retrofit devices, low emission non-catalytic woodstoves, and double wall flue pipe) under "in-home" conditions.
2. Measure the creosote build-up in flue pipes and chimneys of the test stoves.
3. Compare results from this study with other available documented field studies or laboratory tests.
4. Evaluate the impact of "in-home" woodburning operator practices on woodstove performance.
5. Evaluate the percentage of time catalysts were at "lightoff" conditions, i.e., the percentage of time that in-catalyst temperatures were greater than 260° C (500° F).
6. Evaluate the effect on woodstove performance and particulate emissions of using the two types of wood commonly available in the Whitehorse area—"firekilled" (predominantly lodgepole pine) and "seasoned" (predominantly white spruce, two homes used "seasoned" lodgepole pine).

The general design of the study consisted of nine one-week particulate emission sampling periods that were conducted in fourteen Whitehorse homes which used wood as a primary source of heat. After four one-week sampling periods were completed using the homeowners' existing conventional technology woodstoves (Stage 1), new woodheat technology appliances were installed in each of the study homes and monitored for an additional five one-week sampling periods (Stage 2). Woodheat technologies evaluated in this study were:

Stage 1

Technology Type	Woodstove Models	Number of Homes
Conventional	RSF "65"	5
	"Step Top" Spin Drafts	4
	Sears "Automatic"	2
	Blaze King "King"	2
	Energy King "Princess"	1

Stage 2

Technology Type	New Technology Models	Number of Homes
Double Wall Flue Pipe	James A. Ryder Manufacturing (sealed) and Security Chimneys, Ltd. (vented)	2
Low Emission Non-Catalytic Woodstoves	Osburn "Imperial 2000"	2
Catalytic "Add-on" Retrofit Devices	Nu-Tec Catalytic Retrofit	2
	Uni-Com Catalytic Damper	2
Integral Catalytic Woodstoves	Blaze King "King"	2
	Burning Log "Turbo 10"	2
Conventional	Pacific Energy Systems "Super 27" (uncertified version)	2

Throughout the study chimneys were swept and the accumulated creosote was collected and weighed. Creosote accumulation comparisons were made between Stages 1 and 2. The study also included an evaluation of the residential wood combustion effects of "firekilled" and "seasoned" wood that is available in the Whitehorse area.

II. RESULTS AND CONCLUSIONS

Table A summarizes the performance of new woodheat technologies evaluated in this study. Technology performance is listed in five categories: mean emission rate in grams of particulate per hour of stove operation (g/hr); mean burn rate in kilograms of wood used (dry basis) per hour of stove operation (dry kg/hr); mean wood use in kilograms of wood used (dry basis) per heating degree-day (dry kg/HDD); mean overall efficiency as a percentage (%)—an indicator of the energy efficiency of the technology; and creosote deposition in grams of creosote per heating degree-day (g/HDD). A more detailed breakdown of emission performance by technology model is presented in Table B. This study demonstrated the following performance characteristics:

A. Conventional Technology Woodstoves

The conventional technology woodstoves had a mean particulate emission rate of 21.8 grams per hour, which is considered in the low end of the range (typically 20–60 g/hr) for conventional technology woodstoves. Since conventional technology stoves generally produce less emissions under

Table A

Whitehorse Efficient Woodheat Technology Demonstration Project

Summary of Woodheat Technology Performance

Technology	Mean Emission Rate (g/hr)[1]	Mean Burn Rate (dry kg/hr)[2]	Mean Wood Use (dry kg/HDD)[3]	Mean Overall Efficiency (%)	Creosote Deposition (g/HDD)[4]
Conventional Technology Woodstoves	21.8	1.42	1.45	49.8	1.16
Vented Double-Wall Flue Pipe	32.8	1.33	1.26	46.8	1.18
Sealed Double-Wall Flue Pipe	22.9	1.46	1.43	47.3	
Catalytic "Add-On" Devices	16.2	1.40	1.29	55.3	0.81
Low-Emission Non-Catalytic Woodstoves	14.3	1.08	1.03	48.2	0.43
Integral Catalytic Woodstoves	12.1	1.35	1.45	55.9	0.69

1. Emission Rate—grams of particulate per hour of stove operation (g/hr)

2. Burn Rate—kilograms of wood (dry basis) per hour of stove operation (dry kg/hr)

3. Wood Use—kilograms of wood used (dry basis) per heating degree-day (dry kg/HDD)

4. Creosote Deposition—grams of creosote per heating degree-day (g/HDD)

Table B

Whitehorse Efficient Woodheat Technology Demonstration Project

Summary of Woodheat Technology Emission Performance

Technology Type	Technology Model	Emission Rate (g/hr) Mean	Emission Rate (g/hr) Range
Conventional Technology Stoves	All Stoves	21.8	5.7–49.8
Double Wall Flue Pipe	Security Chimneys, Ltd.	32.8	26.4–40.5
	James A. Ryder Manufacturing	22.9	18.0–27.1
Catalytic "Add-on" Retrofit Devices	Nu-Tec Catalytic Retrofit	20.0	11.8–36.6
	Uni-Com Catalytic Damper	13.0	5.6–22.0
Low Emission Non-Catalytic Woodstoves	Osburn "Imperial 2000"	14.3	5.3–22.2
Integral Catalytic Woodstoves	Blaze King "King"	15.5	7.4–25.4
	Burning Log "Turbo 10"	9.0	4.3–15.4

high burn rate conditions, this result is not unexpected since the average burn rate (1.42 dry kg/hr) is relatively high in Whitehorse. Higher burn rates will generally result in lower emissions due to increased firebox temperatures and more complete combustion of the fuel and its combustion gases.

The largest data set collected for a conventional technology woodstove was for the RSF "65" which had mean emission rates for individual homes ranging from 16.8 to 35.3 g/hr. An evaluation of factors (i.e. burn rates, fuel loading frequency, fuel load density, chimney system configuration) that could influence emission performance did not indicate any significant factor contributing to the variation in mean emission rates between homes. While operator practices cannot be ruled out as a contributing factor to the observed variances in emissions rates, a detailed inspection of each RSF "65" would be needed to determine if mechanical factors, e.g. improperly operating thermostats, blocked combustion air supply, etc., are significant influences on stove performance.

The simple step-top stoves produced some of the lowest emission rates, i.e. 6 to 10 g/hr, observed in this study. All of these stoves were primary heat sources and were fueled at relatively high burn rates. This observation also supports the relationship between high burn rates and low emissions. While these stoves have the potential to generate high emissions, it appears that under Whitehorse heat demand conditions they are generally operated in such a manner as to keep emissions relatively low.

B. New Woodheat Technology Performance

1. Double Wall Flue Pipe

a. Vented Type—Security Chimneys, Ltd.

Within three days after the installation of the vented Security double wall flue pipe in one home it was observed that creosote almost completely clogged the pipe, resulting in a severe smoke spillage problem. This problem was not observed during Stage 1 or after the vented pipe was replaced with sealed double wall pipe. It is therefore hypothesized that the vented double wall pipe caused a thermosiphon effect resulting in a rapid cooling of the gases and a concentration of creosote in the flue pipe. Burning creosote was also observed on one occasion in the vented flue pipe of the other home in which it was installed. Additional analysis which is beyond the scope of this project would be needed to confirm if the observed rapid creosote build-up associated with vented double-wall flue pipe would be generally applicable to stove installations and meteorological conditions found in the Whitehorse area.

The double wall vented flue pipe also increased emission rates in both homes in which it was installed.

b. Sealed Type— James A. Ryder Manufacturing

Upon replacement of the vented pipe with sealed double wall pipe, the rapid localized creosote build-up problem observed with the vented flue pipe stopped. Emission rates decreased relative to the vented flue pipe. In comparison to Stage 1, wood usage significantly decreased in home W01 even through the homeowners indicated that the Ryder pipe did not seem to have a noticeable effect on stove performance.

2. Low-Emission Non-Catalytic Woodstoves

While it was originally intended to use two different models of low-emission non-catalytic woodstoves in this study, only one model, namely the Osburn "Imperial 2000," was evaluated. It was discovered at the end of the study that the other model installed in two homes, the Pacific Energy Systems (PES) "Super 27," was an uncertified version (i.e. not Oregon certified). The local dealer of this stove was under the impression that the "Super 27" stoves were Oregon certified.

This unexpected result indicates the need for both dealer and consumer education regarding the identification of certified stoves. The performance data from the two "Super 27" stoves was treated as conventional technology woodstove information.

There were significant differences in the emission performance of the "Imperial 2000" between the homes in which they were installed. In one home, the mean emission rates was 9.6 g/hr and in the other home the rate was 19.0 g/hr. The home with the highest emission rate had a relatively short (3.4 m [11.1 ft.]) chimney system with a mix of 15 cm (6 in) and 20 cm (8 in) diameter pipe while the other home had a 6.9 m (22.6 ft) run of 15 cm (6 in) pipe. It is hypothesized that the straight short chimney with a mix of flue diameters probably contributed to higher emission rates by creating relatively poor draft conditions. Laboratory testing would have to verify this hypothesis.

Participants using the low-emission non-catalytic woodstoves expressed concern about the frequent fuelings required (approximately every 3 to 6 hours) under high heat demand conditions. The shorter burn times required the homeowners to occasionally refuel the stoves during the night. In a smaller and/or well-insulated home or apartment the heat from a low-emission non-catalytic woodstove appears to be sufficient to satisfy heating demand needs in the Whitehorse area.

3. Catalytic "Add-On" Retrofit Devices

The catalytic "add-on" retrofit devices that were installed on conventional technology woodstoves had a mean emission rate of 16.2 grams per hour, which was 26% lower than the mean emission rate observed for the conventional technology woodstoves. The catalytic retrofits also increased the overall efficiency of the conventional technology woodstoves on which they were installed. The mean overall efficiency for the catalytic retrofits was 55.3%. This technology classification demonstrated a potential for reducing particulate emissions from conventional technology woodstoves; however, each home that used catalytic "add-on" retrofits experienced moderate to severe smoke spillage from the stove door when lighting a fire or fueling the woodstove. In one home severe smoke spillage was observed due to the spontaneous ignition of unburned combustion gases. Most smoke spillage problems observed were caused by the retrofit device acting as a flow restriction in the flue pipe. In the homeowners' opinions, the smoke spillage problems generally outweighed any benefit from the catalytic retrofit devices. It appears the severity of the smoke spillage problem can be influenced by the design of the conventional technology woodstove on which the catalytic retrofit device is installed. Further design improvements in catalytic "add-on" devices may be able to reduce or eliminate the type of smoke spillage problems observed in this study.

4. Integral Catalytic Woodstoves

The integral catalytic woodstoves had the lowest mean particulate emission rates and highest overall efficiencies of the Stage 2 technologies evaluated. The mean emission rate observed for the integral catalytic woodstoves was 12.1 grams per hour, which was 44% lower than the conventional technology mean emission rate of 21.8 grams per hour. The mean overall efficiency for the integral catalytics was 55.9%. The homeowners who operated the integral catalytic woodstoves were generally pleased with the heat output, burn times, and mechanical design of the stoves. The integral catalytic woodstoves reduced emissions without sacrificing safety or the convenience of long burns.

As discussed in more detail in Section VI of this report, there were a number of defects found in the emission control system of the Blaze King "King" stoves used in this study. The defects appear to be a combination of installation errors and manufacturing quality assurance problems. Based on laboratory tests conducted on the catalysts used in the Blaze King "King" stoves, it appears that several of the identified emission control system problems contributed to the observed elevated emission rates. The manufacturer of the "King" stoves has already started to take corrective actions as a result of the findings of this study. Despite the observed problems with the Blaze King "King" catalytic stoves, study participants were very pleased with the heat output and burn duration performance of these stoves.

An inspection of the "Turbo 10" stoves also revealed a gap in the gasketing around the catalysts in one stove. However, this gap did not appear to significantly impact the emission performance of the stove during the study.

While it is impossible to make a generic statement about the extent of installation and manufacturing problems discovered by this study, it is an indicator that consumers should request information about the experience of stove installers and their ability to identify and correct manufacturing problems.

While both the Blaze King "King" stoves had the highest catalyst lightoff percentage of any technology evaluated in this study (70.8%), the observed mean emission rate was significantly higher than its Oregon certification level—15.5 g/hr versus 1.6 g/hr. This observation indicates that catalyst performance measurements may not be a good indicator of stove emission performance when there is a failure(s) of the emission control system in catalytic stoves. This observation is also supported by studies conducted by OMNI in the northeastern and northwestern areas of the United States.

C. Creosote Deposition Rate

The double wall flue pipe system did not appear to change the total creosote deposition rates in one home. The creosote deposition rate appears to be significantly reduced in the other home; however, a missing sample in Stage 2 makes this data highly questionable.

The Pacific Energy Systems "Super 27" (uncertified version) has an increased creosote deposition rate when compared with the Stage 1 woodstoves in both of the study homes.

The Osburn "Imperial 2000" had a decreased creosote deposition rate when compared with conventional technology woodstoves in both of the study homes.

In each of the four study homes with the catalytic "add-on" retrofit devices installed, the creosote deposition rate increased between 8.2% and 40.0%. However, the uncertainty associated with the creosote sample collection procedure indicates that the reported increases may be questionable. If this trend can be verified by laboratory tests, it raises additional safety questions about the use of catalytic "add-on" devices.

In three of the four homes with integral catalytic woodstoves, creosote deposition rates as compared with the conventional technology woodstoves appeared to be significantly decreased. In the fourth home the creosote deposition rate appeared to be the same as the creosote deposition rate observed with the conventional technology woodstove.

D. Wood Usage

With the exception of two homes with the Nu-Tec "add-on" device and the one home with the "Imperial 2000" that had relatively high emissions, all other homes showed a decrease in wood use after new woodheat technologies were installed in the Stage 2 sampling period. The Uni-Com catalytic "add-on" damper showed an average reduction in wood usage (dry kg/HDD) of 17.4%, whereas the integral catalytic and the low-emission non-catalytic woodstoves showed average reductions of 14.9% and 13.9% respectively. Caution must be used in the interpretation of wood use data since a number of factors, e.g. woodstove firebox size, overall efficiency, and operator fueling practices, influence wood use figures.

E. Comparison of Results from Whitehorse Study with Other Field Studies and Laboratory Tests

Recent in-situ woodstove studies conducted by OMNI which are still under peer review have also demonstrated a wide range of emission performance of certified stoves. It is expected that upon completion of the peer reviews of the other field studies the Whitehorse Efficient Woodheat Demonstration report results will be compared against studies conducted in the northeastern and northwestern parts of the United States. This type of comparison study should give further insights into significant factors influencing "real world" woodstove performance. Generally, emission rates of certified stoves evaluated in this study were higher than Oregon certification levels. This result is not unexpected in that the Oregon certification process does not take into account all variables encountered under "real world" conditions. In addition, many of the elevated emission rates demonstrated in this study, e.g. those of the Blaze King "King" and PES "Super 27" stoves, can be explained by identified problems with the emission control system or other design factors identified in this study.

F. The Effect of Operator Practices on Woodstove Performance

Operator practices can clearly influence the performance, i.e., emission levels and overall efficiency, of woodheat technologies. However, the data from this study indicates that the design and quality of installation of a particular woodheat technology has a more significant bearing on overall performance than operator practices. The design of a woodstove or catalytic retrofit device will determine a general range of emission rate capabilities. Proper installation and good operating practices (e.g., using dry wood) will increase the probability of achieving the lowest possible emission rates.

G. Fuel Effects—"Firekilled" vs. "Seasoned" Wood

The "firekilled" and "seasoned" fuel used during the study did not show any statistically significant differences in grams per hour emission rate performance as averaged over all technologies. The "firekilled" fuel had a mean emission rate of 19.5 grams per hour, and the "seasoned" fuel had a mean emission rate of 19.3 grams per hour. The "seasoned" fuel had a higher moisture content (29.4%—dry basis) than the "firekilled" (16.6%—dry basis) and the homeowners commented that this fuel was less convenient to start fires with and did not seem to burn as cleanly. The "firekilled" wood is approximately thirty (30) years old and has the same energy content on a dry basis as the "seasoned" wood. Some homeowners also felt that the "seasoned" wood produced more creosote. The creosote collection procedures did not allow this homeowner perception to be evaluated.

III. RECOMMENDATIONS FOR FURTHER ACTION

This study has provided new insights into the desirable performance characteristics and limitations of several new woodheat technologies. The study has also raised some issues that suggest further evaluation. Specifically, they are:

1. The matching of chimney systems to new woodheat technologies and the effect on overall woodstove performance. The potential influence of this factor was best illustrated with the differences in the emission performance of the low emission non-catalytic woodstoves and the observed concentration of creosote deposits in the vented double wall flue pipe.
2. Emission control system durability in integral catalytic woodstoves. The emission control system of typical integral catalytic woodstoves requires the interaction of the mechanical

bypass, catalyst, and primary, secondary and (sometimes) tertiary air draft systems. A study of the emission control system factors which result in consistent low emission performance under both laboratory and in-situ conditions is essential in determining the long term benefits of this technology classification.

3. An analysis of design factors which can reduce smoke spillage in the catalytic "add-on" retrofit devices. Every home in this study equipped with the retrofit devices experienced some degree of smoke spillage. An evaluation of current designs and improved designs could indicate a device that will safely and reliably reduce particulate emissions from numerous conventional technology woodstove models.
4. A more detailed study of the operation and applicability of low emission non-catalytic woodstoves in colder climates. This classification of woodstoves has the potential of reducing particulate emission rates; however, the chimney system, heating demand, willingness of the operator to refuel more frequently, and heat retention characteristics of the home where the device is installed all influence the overall effectiveness and acceptability of the low emission non-catalytic woodstoves. The development of more specific criteria for installations of low emission non-catalytic woodstoves in colder climates is suggested by this study.
5. Emission reduction potential of the sealed airspace double wall flue pipe. The total data set collected on this type of flue pipe consisted of five sampling periods. A larger data set would help to resolve the issue of particulate emission reduction potential of this type of flue pipe.
6. Improved education programs for both consumers and dealers to ensure that new technology woodstoves are properly installed, operated, and maintained. Sponsorship of these programs should be both from the public, e.g. regulatory agencies, and the private sector, e.g. manufacturers of woodstoves and trade organizations.
7. The requirement for random periodic inspections of certified woodstoves at the place of manufacture in the event that a Canadian woodstove emission performance regulation is adopted. This requirement would ensure that manufacturers do not implement changes in design or materials without having the approval of the appropriate regulatory agency.

RESUME

I. CONTEXTE ET OBJECTIFS

Un ensemble imposant de données obtenues lors d'essais en laboratoire a démontré que les nouvelles techniques de chauffage au bois peuvent réduire grandement les émissions de fumée et améliorer l'efficacité globale de ce type d'appareil de chauffage. Afin de déterminer leur efficacité dans des conditions "réelles" (c.-à-d. dans une maison), la ville de Whitehorse a réalisé un projet de démonstration des nouvelles techniques de chauffage au bois. Appuyée par Énergie, Mines et Ressources Canada et par le gouvernement du Yukon, la ville a obtenu un financement pour ce projet, dans le cadre des activités du Programme de démonstration dans les collectivités éloignées (PDCE) et du Laboratoire canadien de recherche sur la combustion. Le Programme et le Laboratoire relèvent tous deux d'Énergie, Mines et Ressources Canada.

Les techniques de chauffage au bois qui ont été étudiées dans ce projet n'avaient pas fait l'objet d'évaluation dans des conditions réelles (dans des maisons). Cette étude avait donc comme objectif global de dégager des conclusions concrètes au sujet de l'efficacité des nouvelles techniques de chauffage au bois, et on a cherché à déterminer dans quelle mesure ces techniques :

1. Réduisent l'impact négatif des émissions de combustion sur la qualité de l'air ambiant.
2. Réduisent les risques associés aux feux de cheminée et à l'utilisation du chauffage au bois dans les maisons.
3. Améliorent le rendement énergétique du chauffage au bois dans les maisons.

L'étude a été expressément conçue en vue des objectifs suivants :

1. Quantifier les émissions attribuables aux techniques classiques et nouvelles de chauffage au bois dans les maisons (poêles à

catalyseur intégré, poêles à catalyseur ajouté, poêles sans catalyseur à faible niveau d'émissions, et cheminées à double paroi) dans des conditions réelles.

2. Mesurer le taux d'accumulation de la créosote dans les conduits d'évacuation et les cheminées couplés aux poêles testés.
3. Comparer les résultats de cette étude avec d'autres études réalisées sur le terrain ou des essais effectués en laboratoire.
4. Évaluer dans quelle mesure le mode d'utilisation du poêle à bois, dans une maison, influe sur son rendement.
5. Évaluer, en pourcentage, le temps pendant lequel les catalyseurs ont fonctionné dans des conditions de chauffe, c'est-à-dire le temps, en pourcentage, pendant lequel les températures à l'intérieur du catalyseur étaient supérieures à 260 °C (500 °F).
6. Évaluer l'effet, sur le rendement du poêle et les émissions de particules, de l'utilisation des deux types de bois que l'on peut habituellement se procurer dans la région de Whitehorse : bois "déjà brûlé" (c.-à-d. du bois provenant de forêts qui ont été incendiées par le passé, soit principalement du pin tordu) et du bois "séché" (principalement de l'épinette blanche et, dans deux maisons, du pin tordu "séché").

L'étude a consisté à recueillir des échantillons d'émissions de particules pendant neuf périodes d'une semaine, dans quatorze maisons de Whitehorse qui étaient chauffées principalement au bois. Après quatre périodes d'échantillonnage d'une semaine réalisées sur les poêles à bois classiques déjà en place dans les maisons (étape 1), on a installé des poêles utilisant des techniques nouvelles dans chaque maison testée, et on a réalisé cinq autres périodes d'échantillonnage d'une semaine (étape 2). Voici les différentes techniques de chauffage au bois qui ont été évaluées au cours de cette étude :

Étape 1

Type de technique	Modèle de poêle	Nombre de maisons
Classique	RSF "65"	5
	"Step Top" Spin Drafts	4
	Sears "Automatic"	2
	Blaze King "King"	2
	Energy King "Princess"	1

Étape 2

Type de technique	Modèle utilisant de nouvelles techniques	Nombre de maisons
Conduit d'évacuation à double paroi	James A. Ryder Manufacturing (conduit scellé), et Cheminée Sécurité Ltée (conduit à aération)	2
Poêle sans catalyseur à faibles émissions	Osburn "Imperial 2000"	2
Poêles à catalyseur ajouté	Catalyseur d'appoint Nu-Tec	2
	Registre catalytique Uni-Com	2
Poêles à catalyseur intégré	Blazer King "King"	2
	Burning Log "Turbo 10"	2
Technique classique	Pacific Energy Systems "Super 27" (modèle non homologué)	2

Tout au long de l'étude, on a ramoné les cheminées, et on a recueilli et pesé la créosote accumulée. On a pu ainsi comparer la créosote accumulée lors de l'étape 1 et lors de l'étape 2. Dans le cadre de l'étude, on a également évalué les effets, sur la combustion, du type de bois utilisé (bois "déjà brûlé" et bois "séché") qui est disponible dans la région de Whitehorse.

II. RÉSULTATS ET CONCLUSIONS

Le tableau A résume le rendement des nouvelles techniques de chauffage au bois évaluées dans cette étude. Les résultats sont présentés en cinq volets : les émissions moyennes en grammes de particules par heure de fonctionnement du poêle (g/h); la cote moyenne de combustion en kilogrammes de bois utilisé (bois sec) par heure de fonctionnement (kg sec/h); la consommation moyenne de bois en kilogrammes de bois utilisé (bois sec) par degré-jour de chauffage (kg sec/DJC); le rendement global moyen exprimé en pourcentage (%), lequel est un indicateur du rendement énergétique de la technique; et enfin le rythme d'accumulation de la créosote en grammes de créosote par degré-jour de chauffage (g/DJC). Le tableau 2 présente une ventilation plus détaillée des niveauc d'émissions, pour les différentes techniques. Cette étude nous permet de dégager certaines conclusions que nous présentons dans les paragraphes suivants.

A. Poêles classiques

Pour les poêles de cette catégorie, on a enregistré, pour les émissions de particules, une valeur moyenne de 21,8 grammes par heure, ce qui se trouve dans la plage inférieure de la fourchette habituellement enregistrée avec les poêles classiques (soit de 20 à 60 g/h). Comme les poêles classiques produisent habituellement moins d'émissions lorsqu'ils fonctionnent à une cadence de combustion élevée, ce résultat n'est pas surprenant, car la cadence de combustion moyenne (1,42 kg sec/h) est relativement élevée à Whitehorse. Des cadences de combustion élevées se traduisent généralement par de faibles niveaux d'émission, car la température élevée qui règne à l'intérieur du poêle assure une meilleure combustion du bois et de ses gaz de combustion.

Tableau A
Projet de démonstration des techniques efficaces de chauffage au bois à Whitehorse

Sommaire des résultats

Technique	Niveau moyen d'émissions (g/h)[1]	Cadence moyenne de combustion (kg sec/h)[2]	Consommation moyenne de bois (kg sec/DJC)[3]	Rendement global moyen (%)	Accumulation de créosote (g/DJC)[4]
Poêles utilisant une technique classique	21,8	1,42	1,45	49,8	1,16
Conduit d'évacuation à double paroi aérée	32,8	1,33	1,26	46,8	1,18
Conduit d'évacuation à double paroi scellée	22,9	1,46	1,43	47,3	
Poêles à catalyseur ajouté	16,2	1,40	1,29	55,3	0,81
Poêles sans catalyseur à faibles émissions	14,3	1,08	1,03	48,2	0,43
Poêles à catalyseur intégré	12,1	1,35	1,45	55,9	0,69

1. Niveau d'émissions - grammes de particules par heure de fonctionnement du poêle (g/h)

2. Cadence de combustion - kilogrammes de bois (bois sec) par heure de fonctionnement du poêle (kg sec/h)

3. Consommation de bois - kilogrammes de bois (bois sec) utilisé par degré-jour de chauffage (kg sec/DJC)

4. Accumulation de créosote - grammes de créosote par degré-jour de chauffage (g/DJC)

Tableau B
Projet de démonstration des techniques efficaces de chauffage au bois à Whitehorse

Sommaire des niveaux d'émissions enregistrés

Type de techniques	Modèle	Niveau d'émissions (g/h) Moyenne	Fourchette
Poêles utilisant une technique classique	Tous les poêles	21,8	5,7-49,8
Conduits d'évacuation à double paroi	Cheminées Sécurité Ltée	32,8	26,4-40,5
	James A. Ryder Mnfg.	22,9	18,0-27,1
Poêles à catalyseur ajouté	Catalyseur d'appoint Nu-Tec	20,0	11,8-36,6
	Registre catalytique Uni-Com	13,0	5,6-22,0
Poêles sans catalyseur à faible émissions	Osburn "Imperial 2000"	14,3	5,3-22,0
Poêles à catalyseur intégré	Blaze King "King"	15,5	7,4-25,4
	Burning Log "Turbo 10"	9,0	4,3-15,4

C'est avec l'appareil classique RSF "65" que nous avons recueilli le plus grand nombre de données; cet appareil a donné un niveau d'émissions compris entre 16,8 et 35,3 g/h dans les différentes maisons. On a évalué les facteurs (c.-à-d. cadence de combustion, fréquence de chargement du combustible, densité de chargement du combustible, configuration de la cheminée) qui pourraient influencer le niveau d'émissions, mais aucun d'entre eux ne contribue de façon marquée à la variation des niveaux d'émissions moyens entre les différentes maisons. Même si on ne peut exclure la façon dont ces poêles sont utilisés par les propriétaires, comme facteur contribuant à l'écart observé des niveaux d'émissions, il faudrait procéder à une inspection détaillée de chaque poêle RSF "65" afin de déterminer si le rendement de l'appareil est fortement influencé par certains facteurs mécaniques, p. ex. un thermostat qui fonctionne mal, un conduit d'alimentation en air comburant qui serait bouché, etc.

Les poêles simples à chargement par le dessus ont donné quelques-uns des plus faibles niveaux d'émission observés dans cette étude, soit 6 à 10 g/h. Tous ces poêles constituaient des sources premières de chauffage et étaient alimentés à des cadences de combustion relativement élevées. Cette constatation étaye la relation entre cadences de combustion élevées et faibles niveaux d'émission. Même si ces poêles peuvent produire des niveaux d'émissions élevés, il semble qu'en raison des conditions climatiques de Whitehorse, ces poêles sont utilisés de manière telle qu'ils produisent des niveaux d'émission relativement faibles.

B. Rendement des poêles utilisant de nouvelles techniques

1. Conduit d'évacuation à double paroi

a. Conduit à aération - Cheminées Sécurité Ltée

Trois jours après avoir installé la cheminé Sécurité à double paroi aérée dans une maison, on a constaté que la créosote avait presque complètement bouché le conduit, ce qui a provoqué un grave problème de refoulement des fumées. On n'a pas observé ce problème pendant l'étape 1, ni après avoir remplacé le conduit à aération par un conduit à double paroi scellée. Par conséquent, on a fait l'hypothèse que le conduit d'évacuation à double paroi aérée avait provoqué un effet de thermosiphon, qui s'est traduit par un refroidissement rapide des gaz et la concentration de créosote dans le conduit de fumée. On a également observé à une autre reprise l'accumulation de créosote dans le conduit d'évacuation aéré qui avait été installé dans une autre maison. Il y aurait lieu de faire des analyses additionnelles, qui dépassent cependant le cadre du présent projet, afin de confirmer si l'accumulation rapide de créosote que l'on a observée dans le conduit d'évacuation à double paroi aérée est attribuable, de façon générale, aux conditions climatiques et aux techniques d'installation des poêles que l'on retrouve dans la région de Whitehorse.

Dans les deux maisons où ce type de conduits d'évacuation a été installé, on a également enregistré une augmentation des niveaux d'émission.

b. Conduit scellé - James A. Ryder Manufacturing

En remplaçant le conduit aéré par un conduit à double paroi scellée, le problème d'accumulation rapide et localisé de créosote, mentionné au paragraphe précédent, a pris fin. Les niveaux d'émissions ont diminué par rapport à ceux qui avaient été enregistrés avec le conduit d'évacuation aéré. Par rapport à l'étape 1, la consommation de bois a diminué de façon marquée dans la maison W01, même si les propriétaires de la maison ont indiqué que le conduit Ryder n'a pas semblé avoir eu un effet notable sur le rendement du poêle.

2. Poêles sans catalyseur à faibles émissions

Bien que l'évaluation devait porter initialement sur deux modèles différents de poêles à bois sans catalyseur à faibles émissions, un seul modèle de ce genre a été évalué, soit le modèle Osburn "Imperial 2000". On a découvert à la fin de l'étude que l'autre modèle installé dans deux maisons, le "Super 27" de Pacific Energy Systems (PES), était un modèle non homologué (c.-à-d. qu'il ne possédait pas l'homologation de l'État de l'Oregon). Le vendeur de ce poêle à Whitehorse était sous l'impression que les poêles "Super 27" possédaient l'homologation de l'Oregon.

Ce résultat surprenant souligne la nécessité de mieux renseigner les vendeurs et les consommateurs au sujet de l'identification des poêles homologués. Par conséquent, les données obtenues avec les deux poêles "Super 27" ont été traités comme s'il s'agissait de poêles utilisant des techniques classiques.

On a observé des différences importantes dans les niveaux d'émissions des poêles "Imperial 2000" installés dans deux maisons différentes. Dans la première maison, le niveau moyen d'émissions était de 9,6 g/h, et dans l'autre maison, il était de 19,0 g/h. Dans cette dernière maison, la cheminée était composée de conduits de diamètre de 15 cm (6 po) et de 20 cm (8 po), tandis que dans la première maison, la cheminée comportait un conduit de 15 cm (6 po) de diamètre, d'une longueur de 6,9 m (22,6 pi). On suppose que la cheminée plus courte comportant des conduits de diamètres différents a contribué à l'augmentation du niveau d'émissions en donnant lieu à un tirage insuffisant. Il faudrait toutefois confirmer cette hypothèse en laboratoire.

Les propriétaires de maisons qui ont participé au projet et qui utilisent des poêles sans catalyseur à faibles émissions se sont montrés préoccupés de ce qu'il faut charger fréquemment le poêle (environ tous les 3 à 6 heures) lorsque la demande de chaleur est élevée. Comme la combustion est rapide, les propriétaires doivent parfois se lever en pleine nuit pour charger leur poêle. Dans les maisons ou appartements bien isolés et (ou) de petites dimensions, la chaleur dégagée par un poêle sans catalyseur à faibles émissions semble suffisante pour répondre aux besoins en chauffage que l'on rencontre dans la région de Whitehorse.

3. Poêles à catalyseur ajouté

Dans le cas des poêles classiques munis d'un catalyseur ajouté, on a enregistré un niveau moyen d'émissions de 16,2 g/h, soit 26 % de moins que le niveau moyen d'émissions enregistré avec les poêles utilisant des techniques classiques. L'adjonction des catalyseurs d'appoint s'est également traduite par une augmentation du rendement global des poêles classiques sur lesquels ils ont été installés. Le rendement global moyen des poêles à catalyseur ajouté a été de 55,3 %. Ce type de technique a donc démontré qu'elle pouvait réduire les émissions de particules attribuables aux poêles classiques; toutefois, dans toutes les maisons qui ont utilisé ce type d'équipement, on a observé des refoulements de fumée, allant de modéré à grave, lorsque l'on ouvrait la porte du poêle afin de démarrer un feu ou de charger l'appareil. Dans une maison, on a observé un grave refoulement de fumée attribuable à l'allumage spontané de gaz de combustion non brûlés. La plupart des problèmes de refoulement de fumée étaient dus au fait que le catalyseur d'appoint nuisait à l'écoulement des gaz et des fumées dans le conduit d'évacuation. De l'avis des propriétaires de maison, les problèmes de refoulement de fumée annulent tout avantage que peuvent procurer les catalyseurs d'appoint. Il semble que la gravité de ce problème peut dépendre de la conception du poêle classique sur lequel le catalyseur d'appoint est installé. En améliorant la conception des catalyseurs d'appoint, on pourrait peut-être réduire ou éliminer les problèmes de refoulement de fumée observés au cours de cette étude.

4. Poêles à catalyseur intégré

Parmi les techniques évaluées au cours de l'étape 2, ce sont les poêles à catalyseur intégré qui ont donné les plus faibles niveaux moyens d'émissions de particules et les rendements globaux les plus élevés. En effet, le niveau moyen d'émissions des poêles à catalyseur intégré a été de 12,1 g/h, soit 44 % de moins que le niveau moyen d'émission enregistré avec les poêles classiques, lequel s'établissait à 21,8 g/h. Le rendement global moyen des poêles à catalyseur intégré a été de 55,9 %. Les propriétaires qui ont utilisé ce type de poêle se sont montrés généralement satisfaits de leur puissance calorifique, de leur conception mécanique et de la durée de combustion qu'ils procuraient. Les poêles à catalyseur intégré ont permis de réduire les niveaux d'émission sans pour autant sacrifier la sécurité ou la commodité que représentent de longues périodes de combustion.

Comme l'indique plus en détail la Section VI du présent rapport, on a observé un certain nombre de problèmes dans le système de régulation des émissions des poêles "King", de Blaze King, évalués dans l'étude. Ces problèmes semblent attribuables à une combinaison d'erreurs d'installation et de contrôle de qualité en usine. D'après les essais réalisés en laboratoire sur les catalyseurs utilisés dans ces poêles, il semble que les niveaux d'émissions élevés observés au cours de l'étude étaient attribuables aux problèmes supposés du système de régulation des émissions. Le fabricant des poêles "King" a indiqué qu'il avait déjà pris des mesures correctives à la suite des conclusions de notre étude. Malgré les problèmes observés avec les poêles à catalyseur "King", les participants à l'étude se sont dits très satisfaits de la capacité calorifique et de la durée de combustion de ces poêles.

L'inspection des poêles "Turbo 10" a révélé la présence d'un vide dans les joints autour des catalyseurs, dans un des appareils. Toutefois, ce vide n'a pas semblé avoir un effet important sur les niveaux d'émissions de ce poêle au cours de l'étude.

Bien qu'il soit impossible de formuler une conclusion générale au sujet des problèmes d'installation et fabrication découverts au cours de l'étude, il n'en demeure pas moins que les consommateurs devraient s'informer au sujet de l'expérience des installateurs de poêles et de leur capacité de déterminer et de régler les problèmes de fabrication.

Même si les deux poêles "King" de Blaze King ont enregistré le plus haut pourcentage (70,8 %) de chauffe du catalyseur, parmi tous les poêles évalués au cours de l'étude, leur niveau moyen d'émissions était beaucoup plus élevé que le niveau indiqué sur le certificat de l'Oregon - 15,5 g/h au lieu de 1,6 g/h. Ce fait semble indiquer que les mesures de rendement des catalyseurs ne sont peut-être pas un bon indicateur du niveau d'émissions produit par un poêle lorsqu'il y a bris du système de régulation des émissions dans les poêles à catalyseur. Cette constatation est également étayée par des études menées par OMNI dans les régions du nord-est et du nord-ouest des États-Unis.

C. Accumulation de créosote

L'utilisation d'un conduit d'évacuation à double paroi n'a pas semblé modifier le rythme d'accumulation de créosote dans une maison. Dans l'autre maison, le rythme d'accumulation de créosote semble avoir été réduit de façon notable; toutefois, un échantillon manquant dans l'étape 2 nous incite à douter fortement de ce résultat.

Dans le cas du "Super 27" (version non homologuée) de Pacific Energy Systems, on a enregistré une augmentation du rythme d'accumulation de créosote par rapport aux poêles de l'étape 1, dans les deux maisons testées.

Pour ce qui est du poêle "Imperial 2000" d'Osburn, on a enregistré un rythme moindre d'accumulation de créosote par rapport aux poêles classiques, et ce, dans les deux maisons testées.

Dans chacune des quatre maisons équipées d'un poêle à catalyseur ajouté, le rythme d'accumulation de créosote a augmenté de 8,2 % à 40,0 %. Toutefois, l'incertitude associée à la méthode de collecte des échantillons de créosote jette un doute sur les augmentations enregistrées. Si ces dernières peuvent être corroborées par des essais en laboratoire, on pourra alors mettre en cause l'aspect sécurité des catalyseurs d'appoint.

Dans trois des quatre maisons équipées d'un poêle à catalyseur intégré, on a enregistré une diminution appréciable des rythmes d'accumulation de créosote, par rapport aux poêles classiques. Dans la quatrième maison, le rythme d'accumulation de créosote semble être demeuré au même niveau que le rythme enregistré avec le poêle classique.

D. Consommation de bois

À l'exception des deux maisons équipées du catalyseur d'appoint Nu-Tec et de la maison équipée du poêle "Imperial 2000" qui avait un niveau d'émissions relativement élevé, on a enregistré dans toutes les autres maisons une diminution de la consommation de bois après l'installations des nouveaux équipements dans l'étape 2. Dans le cas du registre catalytique d'appoint Uni-Com, on a enregistré une réduction moyenne de la consommation de bois (kg sec/DJC) de 17,4 % tandis que l'utilisation des poêles à catalyseur intégré et des poêles sans catalyseur à faibles émissions s'est traduite par une réduction moyenne de 14,9 % et 13,9 %, respectivement. On doit toutefois faire preuve de prudence en interprétant ces données, car il faut tenir compte d'un certain nombre de facteurs, à savoir : dimensions de la chambre de combustion, rendement global, habitudes de chargement des utilisateurs.

E. Comparaison des résultats de l'étude de Whitehorse avec d'autres études sur le terrain et des essais en laboratoire

Les récentes études sur le chauffage au bois menées par OMNI et qui en sont encore à l'étape d'évaluation avant publication, indiquent, au chapitre des niveaux d'émissions, une large fourchette de rendement pour les poêles homologués. Lorsque l'évaluation préliminaire des autres études réalisées sur le terrain sera terminée, on prévoit que le rapport sur le projet de démonstration de Whitehorse sera comparé aux résultats des études effectuées dans le nord-est et le nord-ouest des États-Unis. Ce type de comparaison devrait permettre de comprendre les facteurs importants qui influent sur le rendement des poêles à bois dans des "conditions réelles". En règle générale, les niveaux d'émissions des poêles homologués évalués dans la présente étude sont supérieurs aux niveaux indiqués sur les certificats de l'Oregon. Ce résultat n'est pas surprenant, car la méthode d'homologation retenue par l'État de l'Oregon ne tient pas compte de toutes les variables que l'on rencontre dans les "conditions réelles". En outre, bon nombre des niveaux d'émissions élevés observés au cours de cette étude, notamment ceux enregistrés avec les poêles "King" de Blaze King et "Super 27" de PES, sont explicables par des problèmes que l'on a notés avec les systèmes de régulation des émissions, ou encore par d'autres problèmes relevés au cours de l'étude.

F. Effet des habitudes des utilisateurs sur le rendement des poêles à bois

Les habitudes des utilisateurs ont manifestement une influence sur le rendement de leur poêle, c'est-à-dire sur les niveaux d'émissions et sur le rendement global. Toutefois, les données obtenues au cours de cette étude semblent indiquer que la conception et la qualité de l'installation d'un poêle donné ont plus d'importance sur le rendement global que les habitudes de l'utilisateur. La conception d'un poêle ou d'un catalyseur d'appoint joue un grand rôle dans les niveaux d'émissions imputables à l'appareil. Une installation appropriée et de bonnes habitudes d'utilisation (p. ex., consommer du bois séché) : voilà les deux facteurs qui permettent probablement de réduire le plus possible les niveaux d'émissions.

G. Effets du combustible : bois "déjà brûlé" et bois séché

Le type de combustible - bois "déjà brûlé" et bois séché - utilisé au cours de l'étude n'a pas eu d'effet statistique important sur les niveaux d'émissions, mesurés en grammes par heure, pour l'ensemble des différents appareils. Pour le bois "déjà brûlé", on a enregistré un niveau moyen d'émissions de 19,5 g/h; quant au bois séché, on a enregistré un niveau moyen d'émissions de 19,3 g/h. Le bois séché avait une teneur en humidié supérieure (29,4 %, sur une base sèche) à celle du bois "déjà brûlé" (16,6 %, sur une base sèche), et les propriétaires ont fait valoir que le premier type de bois était moins commode pour démarrer la combustion et qu'il ne semblait brûler aussi proprement que l'autre. Le bois "déjà brûlé" est vieux d'environ 30 ans et a le même contenu énergétique, sur une base sèche, que le bois séché. Quelques propriétaires ont également fait valoir que le bois séché produisait plus de créosote. La méthode de collecte de créosote utilisée au cours de cette étude ne nous a pas permis de vérifier cette hypothèse.

III RECOMMANDATIONS

Cette étude nous a permis de mieux comprendre les caractéristiques de rendement désirables et les limites de plusieurs nouvelles techniques de chauffage au bois. Cette étude a également soulevé quelques questions qui devraient faire l'objet d'une évaluation plus poussée. Les recommandations portent sur les points suivants :

1. Le lien entre les cheminées et les nouveaux appareils de chauffage au bois, et leur effet sur le rendement global des poêles. L'effet possible de ce facteur a été illustré, de façon manifeste, par les différences observées dans les niveaux d'émissions des poêles sans catalyseur à faibles émissions, et les concentrations de créosote enregistrées dans un conduit d'évacuation à double paroi aérée.

2. La durabilité des systèmes de régulation des émissions dans les poêles à catalyseur intégré. Dans ce type de poêle, le système de régulation des émissions fait habituellement appel à l'interaction de plusieurs sous-systèmes : dérivation mécanique, catalyseur, systèmes primaire, secondaire et (parfois) tertiaire de tirage d'air. Il importe d'étudier, autant en laboratoire que dans des conditions réelles, les facteurs associés aux systèmes de régulation qui donnent systématiquement de piètres niveaux d'émissions. Ainsi, on pourra déterminer les avantages à long terme de ce type de technique.

3. Il convient d'analyser les modifications conceptuelles qui permettraient de réduire les refoulements de fumée attribuables aux catalyseurs d'appoint. On a observé, au cours de l'étude, des refoulements de fumée dans toutes les maisons équipées de tels catalyseur. Il y aurait lieu d'évaluer la conception des catalyseurs actuels et d'apporter les améliorations qui s'imposent, afin d'obtenir un dispositif qui réduira, de façon sûre et fiable, les émissions de particules dans de nombreux modèles de poêles classiques.

4. On pourrait étudier plus en détail le fonctionnement et l'utilisabilité des poêles sans catalyseur à faibles émissions dans des climats plus froid. Comme son nom l'indique, ce type de poêle

peut réduire les niveaux d'émissions. Toutefois, le rendement global et l'acceptabilité de ce type d'appareil dépendent de plusieurs facteurs : le type de cheminée, les besoins en chauffage, l'acceptation par l'utilisateur de charger l'appareil plus fréquemment, ainsi que la masse thermique de la maison dans laquelle l'appareil est installé. La présente étude suggère d'élaborer des critères plus précis pour l'installation des poêles sans catalyseur à faibles émissions dans les régions froides.

5. La possibilité de réduire les émissions grâce à l'emploi d'un conduit d'évacuation à double paroi scellée. L'ensemble des données recueillies pour ce type de conduit d'évacuation porte sur cinq périodes d'échantillonnage. Un ensemble de données plus vaste permettrait de savoir si ce type de conduit d'évacuation permet vraiment de réduire les émissions de particules.

6. Il y aurait lieu d'améliorer les programmes d'information des consommateurs et des vendeurs, afin de s'assurer que les poêles utilisant les nouvelles techniques soient installés, utilisés et entretenus de manière appropriée. Le parrainage de ces programmes devrait être assuré par le public (p. ex. les organismes de réglementation) et par le secteur privé (p. ex. les fabricants de poêles à bois et les associations commerciales).

7. Si le Canada adopte une norme sur les niveaux d'émissions des poêles à bois, cette norme devrait prévoir des inspections périodique, en usine et sur une base aléatoire, des poêles à bois homologués. Cette exigence permettrait de s'assurer que les fabricants n'apportent pas des modifications dans la conception ou les matériaux des poêles sans avoir reçu au préalable l'approbation de l'organisme de réglementation approprié.

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I. BACKGROUND

The city of Whitehorse, Yukon Territory, Canada, is located in the south-central part of the Yukon Territory (latitude 60°43'N., longitude 135°03'W.) at an elevation of 670 meters (2200 feet). The city is situated in the Yukon River valley and surrounded by mountainous terrain. Mean total precipitation is 26.03 cm (10.25 in) per year, and daily mean temperatures are 21°C (70°F) in the summer and −24°C (−11°F) in the winter.[1] The city has a population of 17,250 as determined by the 1986 census.[2]

The climate is continental sub-arctic; however, the city is located 150 km (94 miles) from the Gulf of Alaska. Whitehorse is frequently near the boundary between arctic continental and maritime continental air masses. There are frequent periods when a cold continental airmass is well established over the region. During such periods, ground-based temperature inversions resulting in air stagnation conditions often occur.[3] This study was conducted during the period from November to April. During this time the normal heating degree-day accumulation is 5,302.8. For the 1986–1987 heating season (this study) the heating degree-day accumulation was 4,999.9. All heating degree-day data used in this study is based on the Celsius scale.

Wood is a very popular source of heat in Whitehorse because of its relatively low cost and availability. Woodheat in this area is generally less expensive per unit of heat output than fuel oil or electricity. Most of the south-central portion of the Yukon Territory is thickly forested, which provides a good source of firewood. Much of the firewood consumed in Whitehorse is from an area north of the city that experienced a very large forest fire in 1958.[4]

The city has no heavy industry and emissions of air pollutants are considered to be primarily from mobile and domestic sources. Based on studies conducted by Environment Canada, total suspended particulate (TSP) concentrations are generally highest in the Riverdale subdivision. Riverdale is a suburb to the south of Whitehorse that is surrounded on three sides by steep forested slopes and by the Yukon River on the fourth side. The stable air masses coupled with temperature inversions and the topographic setting of the Riverdale subdivision create conditions very favorable to trapping woodstove emissions. Monitoring programs have observed TSP concentrations in Riverdale as high as 589 micrograms per cubic meter ($\mu g/m^3$) for a 24-hour time period.[3] Meteorological analysis suggests that Canadian 24 hour acceptable TSP air quality objective level of 120 $\mu g/m^3$ will be exceeded on one day in three during the heating season.[4]

Wood is a significant residential heating fuel source in Canada. However, health hazards associated with residential wood combustion by-products can be significant. The Canadian Combustion Research Laboratory of Energy, Mines and Resources Canada has researched the effects of woodheating in Canada and has helped governmental agencies implement education programs designed to increase public awareness of efficient wood burning practices. The City of Whitehorse has implemented a by-law which enforces no-burn hours when weather conditions indicate an impending inversion. Along with the regulatory program, the City of Whitehorse also has implemented an education program on how to properly operate woodstoves.

Previous studies on the effects of woodheating in the Whitehorse area have included monitoring of TSP and polynuclear aromatic hydrocarbon (PAH) concentrations[1,3,4,5], surveys of private homes regarding wood fuel use[6], and a study which researched epidemiological effects of woodsmoke in the Riverdale subdivision.[2]

Extensive laboratory data on new residential woodheat technologies has indicated the potential for reducing particulate emissions. New technological developments designed to reduce emissions include the use of a catalyst (as either an integral part of the woodstove or a retrofit device) and the use of more advanced air draft and baffling systems. In an effort to determine the effectiveness of the new technologies, the City of Whitehorse, supported by Energy, Mines and Resources Canada and the Government of the Yukon, secured funding under the Remote Community Demonstration Program and the Canadian Combustion Research Laboratory, both of Energy, Mines and Resources Canada to conduct an "in-home" demonstration of the performance of the new residential woodheat technologies.

II. STUDY OBJECTIVES

This study was designed to focus on the performance of several types of new woodheating technology in fourteen Whitehorse homes. The technologies evaluated in this study had been tested under laboratory conditions; however, they had not been evaluated under "in-home" Canadian conditions. The general goal of the study was to reach meaningful conclusions regarding the effectiveness of each new woodheat technology at:

1. Reducing the impact of residential woodheat emissions on ambient air quality.
2. Reducing the risk associated with chimney fires and safety of operation in the home.
3. Improving the energy efficiency of residential woodheating.

The study was specifically designed to achieve the following objectives:

1. To quantify the emission characteristics of both conventional and new residential woodheat technologies (integrated catalytic woodstoves, catalytic "add-on" retrofit devices, and low emission non-catalytic woodstoves) under "in-home" Canadian conditions. (While the original objective was to have twelve homes with installed new woodheat technologies, it was discovered at the end of the study that two homes had uncertified versions of what were believed to be Oregon-certified low-emission non-catalytic stoves. Stove performance data collected from these homes was treated as conventional technology woodstove information.)
2. To evaluate the effects on woodstove performance of replacing single wall flue pipe with double wall flue pipe. Two homes would have the existing single wall flue pipe portion of the interior chimney replaced with double wall flue pipe.

3. To measure the creosote build-up in flue pipes and chimneys of the test stoves.
4. To compare results from this study with other available field studies or laboratory tests.
5. To evaluate the impact of "in home" woodburning habits on woodstove performance.
6. To evaluate the percentage of time that catalysts were at "lightoff" conditions.
7. To evaluate the effect on woodstove performance and particulate emissions of using the two types of wood commonly available in the Whitehorse area—"firekilled" (lodgepole pine) and "seasoned" (predominantly white spruce, two homes used "seasoned" lodgepole pine).

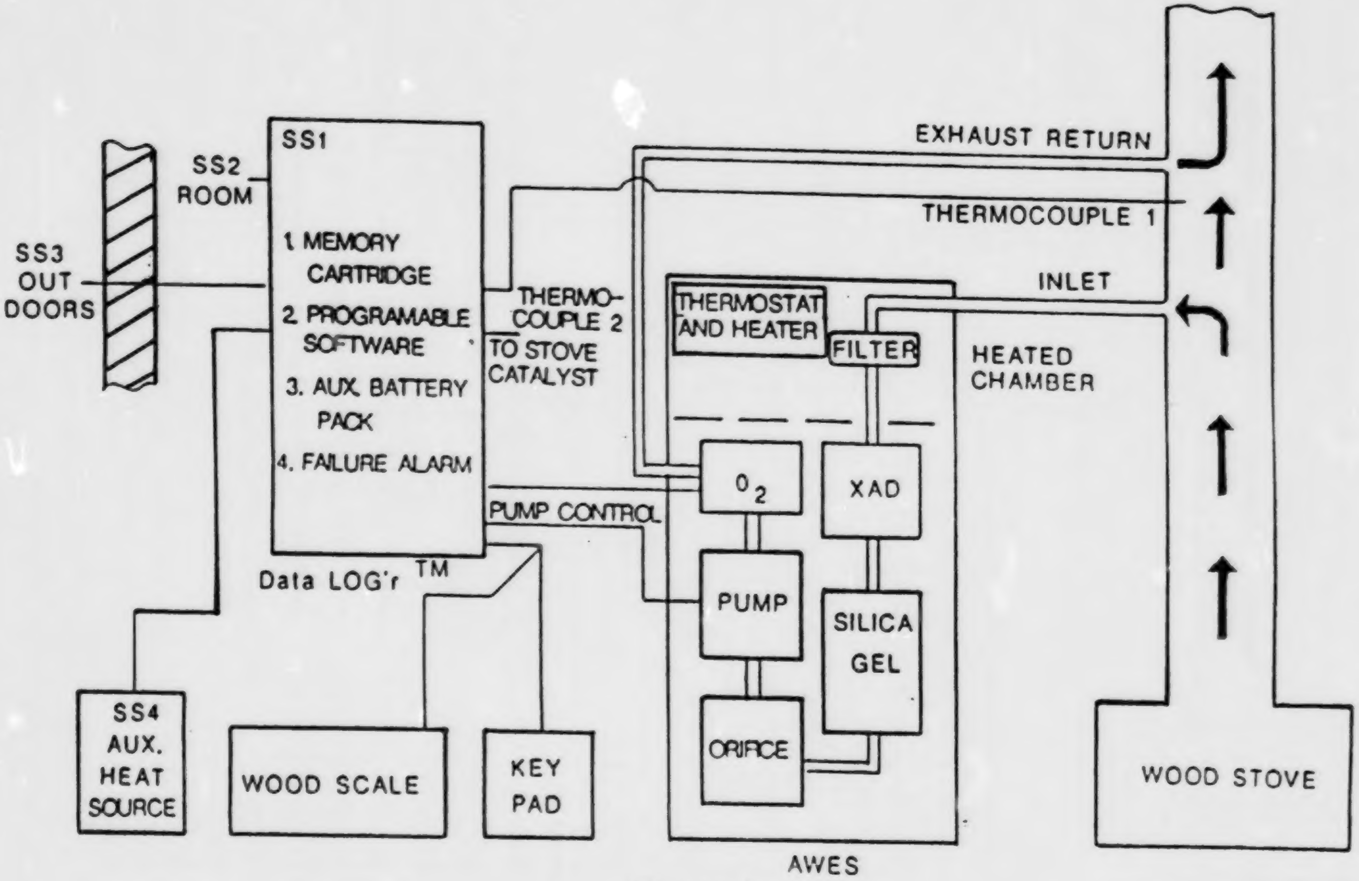
III. SAMPLING EQUIPMENT DESCRIPTION

In response to the necessity of evaluating particulate emissions and wood use data under in-situ conditions, OMNI has developed the AWES/Data LOG'r sampling system. Figure 1 shows a schematic of the AWES/Data LOG'r system. For the non-catalytic technology (conventional technology, low emission non-catalytics, and double-wall flue pipe) a single AWES unit was used to sample at a point 30 cm (1 ft) downstream of the stove's flue collar. For the catalytic technology (integral catalytic woodstoves and catalytic retrofit devices) two AWES units simultaneously sampling were used to obtain particulate emission samples before and after the catalyst. Figure 2 shows a schematic of the dual AWES/Data LOG'r system used for catalytic technology performance assessments.

A. Data LOG'r Description

The Data LOG'r is a multi-channel programmable microprocessor/controller with the capability of processing both digital and analog signals. The unit has data storage capacity of 32 kilobytes on a field-replaceable non-volatile memory data cartridge. As presently programmed, cartridge capacity allows up to 30 days of continuous operation between servicing in most field project applications. The Data LOG'r was programmed to record and store the following information:

- Starting date, time, and unit serial number for data recording periods;
- Daily date and time, recorded at midnight, and a continuous time record in 5 minute intervals;
- Flue gas and, where applicable, in-catalyst and before-catalyst temperatures, averaged over 5-minute intervals (non-catalyst technology) or 15-minute intervals (catalyst technology).
- Room temperature, outdoor temperature (in two study homes), and Data LOG'r ambient temperature in 15 minute intervals;
- Record of alternate home heating status (on or off) by use of a temperature sensor;
- Wood weights and coalbed condition recorded as the woodstoves were fueled;
- Oxygen measurements when the AWES unit was sampling;
- Home AC power status, measured at 5 minute intervals.



SS3
OUT
DOORS
SS2
ROOM
SS1
1. MEMORY CARTRIDGE
2. PROGRAMABLE SOFTWARE
3. AUX. BATTERY PACK
4. FAILURE ALARM
Data LOG'r TM
THERMO-COUPLE 2
TO STOVE CATALYST
PUMP CONTROL
SS4 AUX. HEAT SOURCE
WOOD SCALE
KEY PAD
THERMOSTAT AND HEATER
FILTER
0_2
XAD
PUMP
SILICA GEL
ORIFICE
AWES
HEATED CHAMBER
EXHAUST RETURN
THERMOCOUPLE 1
INLET
WOOD STOVE

Figure 1

AWES/Data LOG'r System

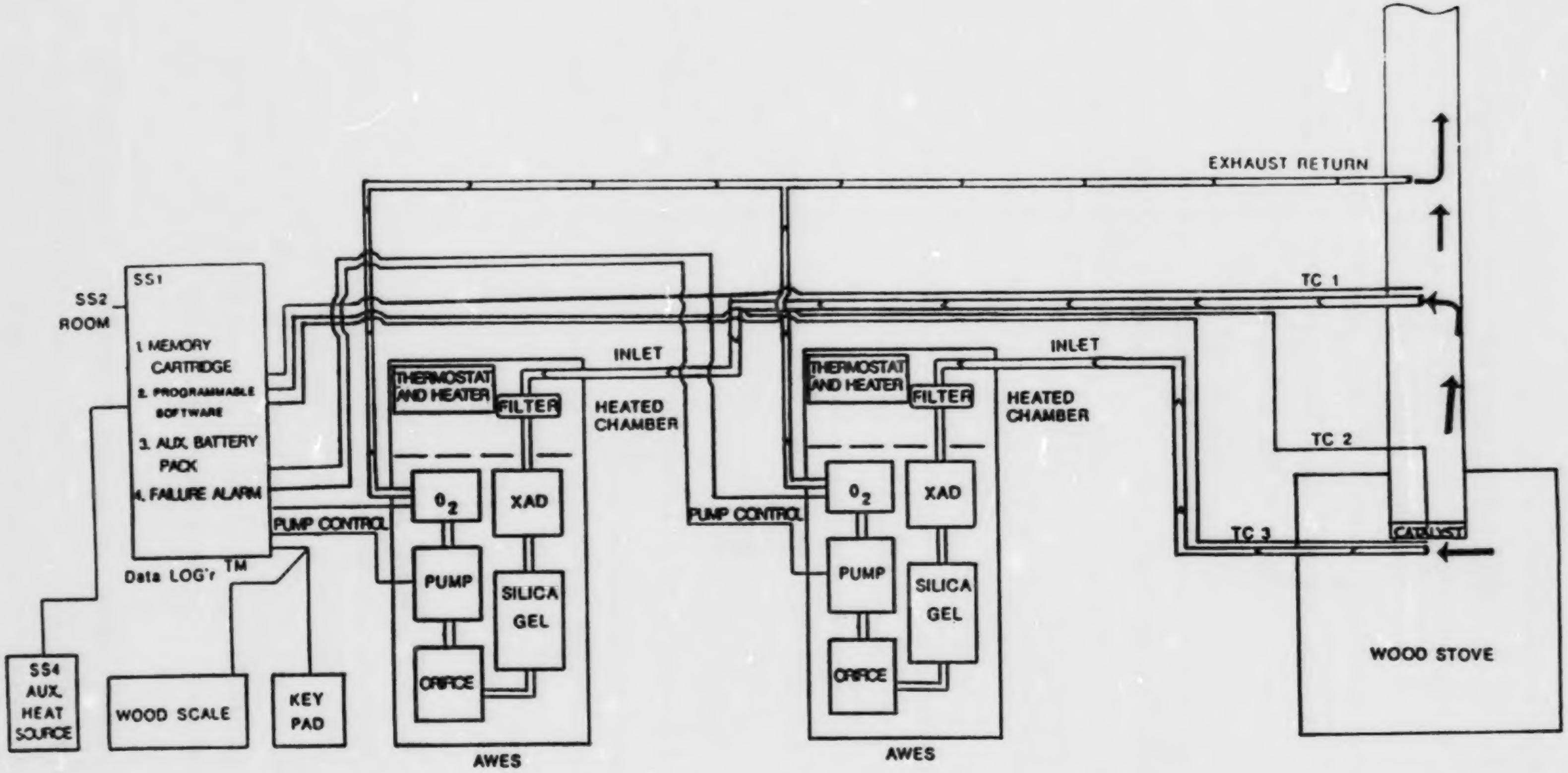

EXHAUST RETURN
TC 1
TC 2
TC 3
CATALYST
WOOD STOVE
SS1
SS2
ROOM
1. MEMORY CARTRIDGE
2. PROGRAMMABLE SOFTWARE
3. AUX. BATTERY PACK
4. FAILURE ALARM
Data LOG'r TM
PUMP CONTROL
INLET
THERMOSTAT AND HEATER
FILTER
HEATED CHAMBER
0₂
XAD
PUMP
SILICA GEL
ORIFICE
AWES
INLET
THERMOSTAT AND HEATER
FILTER
HEATED CHAMBER
PUMP CONTROL
0₂
XAD
PUMP
SILICA GEL
ORIFICE
AWES
SS4 AUX. HEAT SOURCE
WOOD SCALE
KEY PAD

Figure 2

Dual AWES/Data LOG'r System

An attached electronic scale/woodbasket unit supplies to the Data LOG'r an analog voltage output that is linearly proportional to the weight placed in the wood holder. Scale readings were recorded by having the participant use an attached keypad in a prescribed sequence. The five button keypad also allows the participant to record the coalbed conditions at each time of stove fueling.

The Data LOG'r was programmed to activate the AWES unit (two AWES units in the case of the catalytic technology) at a specific date and time. Sampling intervals were one minute on per half hour for seven day sampling periods, commencing on Sundays at midnight.

B. Automated Woodstove Emission Sampler (AWES) Description

The AWES sampler was specifically designed for sampling residential woodstove particulate emissions. As programmed in this study it is capable of sampling woodstove emissions for periods up to one week in length. Sample flow is maintained by a critical flow orifice, so no adjustment is required during operation. Sample start and stop times, dates, and frequency (minutes on and minutes off) are programmable and controlled by the OMNI Data LOG'r. The sampler (two samplers in the case of catalytic technology) was installed prior to a scheduled start time, left unattended, and removed for sample processing at the end of the sampling period.

The AWES unit draws flue gases through a 1.0 cm ($^3/_8$ in) stainless steel probe, 1.0 cm ($^3/_8$ in) Teflon line, and heated U.S. EPA Method-5 type filter for collection of particulate matter, followed by a sorbent resin (XAD–2) trap for semi-volatile hydrocarbons. Water vapor is removed by a silica gel trap. Flue gas oxygen concentrations, which are used in conjunction with wood use data to determine flue gas volume, were measured by an electrochemical cell. The oxygen cell used in the AWES unit is manufactured by Catalyst Research (Model #472062). The AWES uses a critical orifice (Millipore #XX5000002) to maintain a nominal sampling rate of 1.0 liters per minute (0.035 cfm). Each AWES critical orifice is calibrated to determine the exact sampling rate.

C. Probe Placement

The Data LOG'r system uses several external sensors which generate analog voltages that are processed by the Data LOG'r microprocessor. Solid state temperature sensors (National Semiconductor LM334) were used to monitor Data LOG'r box temperature (SS#1), room temperature (SS#2), outdoor temperature (SS#3), and auxiliary heating system status (SS#4). The room temperature sensor was placed on a wall approximately 3.0 m (10 ft) from the stove and approximately 1.2 m (4 ft) above floor level. The auxiliary heat status sensor was placed in the nearest furnace duct or electric baseboard heater.

Type "K" ground-isolated stainless steel sheathed thermocouples (Pyrocom 1K–27–5–U) were used to monitor various flue gas temperatures. In the case of non-catalytic technology, one thermocouple was placed 30 cm (1 ft) downstream of the woodstove's flue collar in the center of the flue gas stream. In the case of the catalytic "add-on" retrofit devices, the before-catalyst thermocouple (TC#3) was placed at the base of the catalytic retrofit housing, the in-catalyst (TC#2) thermocouple was placed as closely as possible to the top of the catalyst while allowing for catalyst movement, and the downstream (flue collar) thermocouple (TC#1) was placed 30 cm (1 ft) downstream of the catalytic retrofit housing. All thermocouples were placed in the center of the flue gas stream. In the case of the integral catalytic woodstoves, the before-catalyst thermocouple (TC#3) was placed in the center of the firebox just upstream of the secondary air intake, the in-catalyst thermocouple (TC#2) was inserted into the center of the catalyst substrate, and the after-catalyst thermocouple (TC#1) was placed 30 cm (1 ft) downstream of the woodstove's flue collar in the center of the flue gas stream.

With the exception of the firebox AWES probes used in the integral catalytic woodstoves, all stainless steel probes used for sampling were 38 cm (15 in) long and 1.0 cm ($^3/_8$ in) OD. The probes were inserted 8 cm (3 in) into the gas stream.

The before-catalyst AWES probes used in the Burning Log "Turbo 10" integral catalytic woodstoves were 52 cm ($20^5/_8$ in) long and inserted 22 cm ($8^5/_8$ in) into the firebox. The tip of the probes were located in the center of the firebox just before the secondary air intake.

The before-catalyst probe used in the Blaze King "King" integral catalytic woodstove was 66 cm (26 in) long and inserted 36 cm (14 in) into the firebox. The tip of the probe was located in the center of the firebox just before the secondary air intake.

The AWES units returned exhaust gas to the stack via a 0.6 cm ($^1/_4$ in) Teflon line and a 38 cm (15 in) stainless steel probe inserted approximately 38 cm (15 in) downstream of the flue collar sampling probe. In installations where two AWES units were used, exhaust gas was returned to the stack via a common 0.6 cm ($^1/_4$ in) Teflon line and 38 cm (15 in) stainless steel probe.

IV. TECHNICAL APPROACH

A. General Study Design

Emission and other performance data was collected on the conventional technology woodstoves prior to the installation of the new technology woodstoves, catalytic retrofit devices, or double-wall flue pipe. During Stage 1, four one-week sampling periods were completed in each of the fourteen homes participating in the study. Creosote samples were collected and particulate emission rates, burn rates, and efficiency of the conventional technology woodstoves were determined during Stage 1.

After the completion of Stage 1 sampling, the new woodheat technologies were installed in the fourteen homes. During Stage 2 five one-week sampling periods were completed. During the five sampling periods, creosote samples were collected and data was obtained on particulate emission rates (both before-catalyst and after-catalyst), burn rates, and overall woodstove efficiencies.

B. Home Selection

The City of Whitehorse, Energy, Mines and Resources Canada, and OMNI cooperated in the selection of homes for the study. OMNI provided a set of preferred selection criteria for the homes participating in the study. In cooperation with OMNI, representatives of the City of Whitehorse and Energy, Mines and Resources Canada conducted interviews of potential participants. Fourteen homes were selected which best met the selection criteria. Requirements for participation in the study included:

1. Currently heat with a conventional technology woodstove. Single wall flue pipe was preferred, and the woodstove was required to be in an installation that met local safety codes.
2. Wood was used as a primary source of heat in the home.
3. Participant was able to provide reasonable access to the home for servicing sampling equipment, chimney sweeping, and technology changes prior to Stage 2.
4. Floor area in the vicinity of the woodstove installation would accommodate the OMNI sampling equipment (temperature sensors, power cords, thermocouples, woodbasket/scale unit, and AWES/Data LOG'r).
5. Participant was willing to try the new technology and to cooperate with the study requirements, specifically, equipment servicing calls, contracted chimney sweeping, use of the Data LOG'r scale/keypad unit, use of "seasoned" and "firekilled" fuel during prescribed periods, and maintenance of a log book of unusual events.
6. Participant was willing to participate in the organization and training sessions conducted by the City of Whitehorse, Energy, Mines and Resources Canada, and OMNI.
7. The existing woodstoves evaluated in Stage 1 were representative of the stove models most commonly used in Whitehorse.

Of the fourteen homes chosen to participate in the study, seven were located in the Riverdale subdivision, and seven were located in the Porter Creek subdivision. The Riverdale subdivision is a suburb to the south of Whitehorse where the highest TSP levels are generally observed.[3] The Porter Creek subdivision is a suburb located north of Whitehorse. Porter Creek is on a bluff west of the Yukon River and generally does not experience as severe air stagnation and elevated TSP episodes as other parts of the city.

C. Technology Selection

The new technology devices were selected by the City of Whitehorse and Energy, Mines and Resources Canada with assistance from OMNI. All new technology woodstoves (both catalytic and non-catalytic) used in this study were certified to meet the State of Oregon 1988 woodstove emission standards and Canadian safety standards. A preference in selecting stoves was also given to woodstoves manufactured in Canada. The new woodheat technologies and double wall flue pipe used in Stage 2 of the study included:

1. Double Wall Flue Pipe:
    a. Security (ventilated airspace)
    b. James A. Ryder (sealed airspace)
2. Low Emission Non-Catalytic Woodstoves:
    a. Osburn "Imperial 2000"
3. Catalytic "Add-on" Retrofit Devices:
    a. Nu-Tec Catalytic Retrofit
    b. Uni-Com Catalytic Damper
4. Integral Catalytic Woodstoves:
    a. Blaze King "King"
    b. Burning Log "Turbo 10"

The Oregon certified version of Pacific Energy System's "Super 27" low emission non-catalytic woodstove was also selected to be used in Stage 2. As discussed in more detail in Section VI, it was discovered at the end of the study that the PES "Super 27" stoves (two homes) used in Stage 2 were not Oregon certified versions of the "Super 27". Therefore, the PES "Super 27" stoves used in this study are considered conventional technology woodstoves.

At the conclusion of sampling period 3 in Stage 1 of the study an evaluation of the burn rates, heating requirements, and fueling frequency for each conventional technology woodstove in each home was completed. A determination of the most appropriate assignment of each new woodheat technology in each participating home was made based on heating requirements, fueling habits of the participants, and compatibility with the existing woodstove installation and/or chimney system dimensions.

D. Training of Study Participants

After the interview and selection process was completed and the fourteen participants were identified, a meeting was conducted in Whitehorse by the City of Whitehorse, Energy, Mines and Resources Canada, and OMNI Environmental Services, Inc. Participants were given a general overview of the study objectives, study design, and participation requirements.

During the initial installation of the instrumentation study participants were instructed by field staff in the proper use of the OMNI Data LOG'r scale/keypad unit and provided with an instruction/log booklet.

After installation of the Stage 2 new technology, participants were given instructions by OMNI field staff on the safe and proper operation of their new woodheat technology devices. Participants using catalytic technology were briefly instructed on the theory of catalytic combustion and how to achieve and maintain catalytic light-off conditions. A schedule was also provided as to when to switch from "firekilled" to "seasoned" fuels. Participants using catalytic add-on devices on the RSF "65s" were instructed to leave the bypass damper in the "open" position to increase the probability of catalyst light-off conditions by increasing the flue gas temperatures. Study participants were also given instruction booklets provided by the manufacturers of each new woodheat technology.

Field staff continued to monitor the operation of the new woodheat technologies during equipment service calls and provided on an as-needed basis additional advice on the proper operation of the new woodstoves and catalytic retrofit devices.

The homes with the double wall flue pipe required little training because no additional changes were made to their existing conventional technology stoves.

The low emission non-catalytic stoves generally required smaller fuel loads and had shorter burn times than the participant's conventional technology woodstoves. Some alteration of previous fueling habits was necessary in the operation of the low emission non-catalytic woodstoves due to the smaller fireboxes.

The catalytic "add-on" retrofit devices required more instruction time than other new woodheat technologies. All participants with catalytic retrofit devices were given additional instruction in establishing an adequate draft condition prior to opening the stove door in order to reduce smoke spillage. Also, additional instruction was given on how to achieve and maintain catalyst lightoff conditions.

The participants with the integral catalytic woodstoves were briefly instructed in the theory of catalytic operation and operating the controls on their new woodstove. No additional training was necessary after the initial training session.

E. Sampling Regime

The emission sampling equipment was installed by OMNI personnel in each of the study homes between November 19, 1986, and November 29, 1986. During this time period the chimneys were swept just prior to the installation of the instrumentation. Woodpile moisture and dimension measurements were recorded. All wood moisture measurements were performed using a Delmhorst moisture meter (Model #RC-1C). Appendix A contains information regarding the accuracy of the Delmhorst meter readings over a wide range of fuel moisture contents and its impact on emission and efficiency calculations. The participants were given instructions on the operation of the Data LOG'r keypad/scale unit and provided with a log book for recording unusual events.

During Stage 1 four one-week sampling periods were completed. Field staff visited each study home to service the sampling equipment at the start and end of each sampling period. At the start of each sampling period, the AWES unit was installed; leak checks were performed; thermocouples, the woodbasket/scale unit, and the oxygen cell were calibrated; the Data LOG'r was programmed with the proper sampling interval and start/stop times; and wood moisture measurements were performed on the fuel in the home's storage area. At the end of each sampling period, end-of-sampling-period calibrations and leak checks were performed; the AWES unit, sampling line, and sampling probe were removed; and wood moisture measurements were performed on the fuel in the home's storage area.

The Data LOG'rs were programmed to activate the AWES units for one minute per half hour for seven days. The participating homes were separated into two sampling groups. Group A consisted of homes W01 through W07, and Group B consisted of homes W08 through W14. Emission sampling in Group A and Group B homes occurred on alternate weeks. For example, during the week while Group A woodstove emissions were being sampled, field personnel removed, serviced, and reinstalled the AWES units and sampling probes in the Group B homes. All sampling periods commenced on Mondays at 0000 hours. Ian Matthews and Karen Larson were responsible for maintaining and calibrating all sampling and data logging equipment.

All new woodheat technologies used in Stage 2 were installed by a licensed installer according to local code. Additional instrumentation (consisting of two additional thermocouples and a second AWES unit) was installed in the homes using the catalytic-equipped technologies. The additional instrumentation enabled catalyst lightoff activity to be evaluated and a before-catalyst emission sample to be collected. For each participating home, five one-week integrated particulate emission samples were collected during Stage 2 sampling.

At the conclusion of Stage 2 sampling all instrumentation was removed from each home. Final woodpile dimension and moisture measurements were recorded between April 4 and April 13, 1987.

F. Creosote Collection Procedure

Chimney sweeping and creosote sample collection was performed under a contract between a local sweeping service and the City of Whitehorse. Veenhof's Chimney Sweeping Service was initially contracted for the sweeping and collected creosote samples through February 20, 1987. After February 20, 1987, the chimney sweeping/creosote sampling was performed by Lawrence T. Vano.

The sweeps collected the creosote in a plastic bag which was weighed on a triple beam balance by OMNI field staff.

Chimneys were swept at the start of the study prior to sampling, monthly or on an as-needed basis during the Stage 1 sampling periods, just prior to the installation of the Stage 2 new woodheat technologies, monthly or on an as-needed basis during the Stage 2 sampling periods, and at the end of the study.

G. Fuel

Two types of wood fuel available in the Whitehorse area were evaluated for potential differences in particulate emission rates and heating characteristics during both Stage 1 and Stage 2. The two classifications of wood types that were used are commonly referred to as "firekilled" and "seasoned."

The "firekilled" wood was cut from a large area north of Whitehorse that burned in 1958. The "firekilled" species was predominantly lodgepole pine.

The "seasoned" fuel was cut from local forests and allowed to season for at least one year. The species of the majority of "seasoned" fuel in the study was white spruce. In homes W01 and W13 "seasoned" lodgepole pine that had been cut by the participants was used instead of white spruce.

The "firekilled" fuel was used during sampling periods 1, 2, 5, 6, and 7. The "seasoned" fuel was used during sampling periods 3, 4, 8, and 9. Several participants burned a mixture of "firekilled" and "seasoned" fuel during the sampling periods that had been designated for "seasoned" fuel only due to difficulties in maintaining a fire with only "seasoned" wood.

H. Laboratory Procedures

Each AWES unit was cleaned and prepared with a new filter and a XAD–2 sorbent resin cartridge prior to field installation. After each sampling period the stainless steel sampling probe, Teflon sampling line, and AWES unit were removed from the study home and transported to a laboratory for processing. Prior to transporting the AWES unit the sample intake port, sampling line, and sampling probe were sealed. The components of the AWES samplers were processed as follows:

1. Filters: Glass fiber filters were removed from the AWES filter housings and placed in petri dishes. The petri dishes were sealed and shipped to OMNI's Oregon laboratory for desiccation and gravimetric analysis for particulate catch.
2. XAD–2 Sorbent Resin: Sorbent resin cartridges were capped and shipped to OMNI's Oregon laboratory. In the OMNI laboratory the cartridges were extracted in the Soxhlet extractor with dichloromethane for 24 hours. The extraction solvent was transferred to a tared glass beaker. The solvent was evaporated in an ambient air dryer, the beaker and residue desiccated, and the extractable residue weight determined.
3. AWES Hardware: All hardware which was in the sample stream (stainless steel probe, Teflon sampling line, glass filter housing, and all Teflon, glass, and stainless steel fittings) through the base of the sorbent resin cartridge was rinsed with dichloromethane and methanol solvents. The solvents were placed in 500 ml glass jars which were capped, sealed, and shipped to OMNI's Oregon laboratory. In the OMNI laboratory the solvents were placed in tared glass beakers. The solvents were evaporated in an ambient air dryer, desiccated, and weighed to determine the residue fraction weight.

After cleaning, the AWES units were reassembled for field use. The intake port, sampling probe, and sampling line were sealed for transportation to the study home, and unsealed immediately prior to installation.

I. Data Processing and Quality Control Procedures

Data files stored in the Data LOG'r memory cartridges were downloaded in the field with a portable computer onto floppy disks at the conclusion of each sampling period. The files were transferred to OMNI's Oregon office from Whitehorse via computer modem. Each data file was reviewed immediately to check for proper equipment operation. Data LOG'r files were used in conjunction with the AWES particulate sample and wood moisture data to calculate particulate emission rates, catalyst lightoff times (when applicable), stove operation time, overall thermal efficiency, and burn rates.

The Data LOG'r data files, log books, and records maintained by field staff were frequently reviewed to ensure sample integrity. Any parameter or calibration objective that did not meet OMNI's in-house quality control criteria was flagged and noted. The emission rate calculations that incorporated a flagged quality assurance parameter were carefully reviewed and are footnoted in the data tables.

Particulate emission rate data is presented with associated precision and accuracy figures. Each individual measurement that is used in the emission calculations has some degree of uncertainty associated with it, and these uncertainties are propagated to determine the precision and accuracy attached to each calculated particulate emission rate. Appendix B lists the calculation procedures used for particulate emission rate determinations. Appendix C summarizes the criteria used in the precision and accuracy calculations.

Two field blank samples were collected with the AWES units in Whitehorse to evaluate potential particulate contamination of the AWES fittings and sampling lines. An additional five field blank samples were also evaluated in the Portland area using identical sampling equipment. The field blank AWES units were prepared according to normal sampling protocols, transported to a study home, leak checked, left unattended for one week without being programmed to sample, leak checked, and transported back to the Whitehorse laboratory for sample processing. The mean particulate catch from the field blanks (22.5 mg; σ: 10.0; range 7.2–35.5 mg) was subtracted from the total particulate catch for each emission sample. The mean field blank value is 7.1% of the average total AWES particulate catch for all sampling periods.

The creosote gravimetric data was compiled for each project stage and normalized using heating degree-day data collected by the Canadian weather service station at the Whitehorse airport.

V. WOODHEAT TECHNOLOGY DESCRIPTION

A. Conventional Technology Woodstoves (Stage 1)

Several models of existing conventional technology woodstoves were evaluated in the study. The following briefly describes the characteristics of each type of conventional technology woodstove evaluated in the study:

1. RSF Energy Limited "Model 65":

This woodstove model is extremely popular in the Whitehorse community and throughout Canada because of its high heat output capability, long burn times, and large firebox (the usable firebox volume is 0.1348 m^3 [4.76 ft^3]). The firebox is constructed of welded steel plate. The "65" primary air intake is thermostatically controlled. The primary combustion air enters the firebox on both sides near the top of the firebox. The air flow is directed down toward the fuel and out of the firebox through a rectangular opening at the lower rear of the firebox. Secondary air enters the stream at the rear of the firebox via a heat exchanger. The flue gas is routed up the rear of the stove and out the 17.8 cm (7 in) top-exit flue collar. The "65" also has a bypass mechanism. In the bypass mode flue gas is routed to the top rear of the firebox, through the bypass door, and directly out the flue collar, bypassing the secondary air system.

2. Fisher "Papa Bear," "Mama Bear," and "Grandma Bear," and Acorn "Ranger":

Each of these stoves uses a similar design. The usable firebox volumes are 0.1039 m^3 (3.67 ft^3), 0.0773 m^3 (2.73 ft^3), 0.0997 m^3 (3.52 ft^3), and 0.1510 m^3 (5.33 ft^3) respectively. Each stove model is constructed of welded steel plate. Each of these stoves uses two spin draft mechanisms mounted on the fuel loading door to control the primary air intake and has a step top design style. The primary combustion air enters each stove at the front of the firebox and is directed through the firebox and directly out the flue collar. The "Ranger" has an integral electric fan that is installed in the top of the firebox. The "Ranger" and "Grandma Bear" have top-exit flue collars, and the "Papa Bear" and "Mama Bear" use rear-exit flue collars. The "Mama Bear", "Papa Bear" and "Ranger" have 15.2 cm (6 in) diameter flue collars, and the "Grandma Bear" has a 20.3 cm (8 in) diameter flue collar.

3. Sears "Automatic":

The "Automatic" has a usable firebox volume of 0.0821 m^3 (2.90 ft^3). The inner firebox is constructed of welded steel plate. The fuel loading door is on the right side of the stove. The primary combustion air enters the firebox through a thermostatically controlled flap located at the lower right of the front stove wall. The primary air enters the firebox through a grate that forms the bottom of the firebox. The air travels through the combustion zone and out the 15.2 cm (6 in) diameter rear-exit flue collar. The "Automatic" firebox is surrounded by a sheet metal housing that has a screen vent at the front of the stove. A thermostatically controlled electric fan is mounted on the rear of the stove and directs convection air between the inner firebox and the sheet metal shell.

4. Pacific Energy Systems "Super 27" (uncertified version; Stage 2 only):

The "Super 27" has a usable firebox volume of 0.0490 m^3 (1.73 ft^3) and is constructed of welded steel plate. A 35.6 cm × 32.1 cm (14 in × $12^5/_8$ in) baffle plate manifold forms the top of the firebox. The manufacturer recommends the use of 35 cm (14 in) logs.

Primary combustion air enters the stove through two openings on the underside of the firebox. The primary air entering the 6.4 cm ($2^1/_2$ in) diameter opening is routed through a manifold to channels in both front corners of the firebox and then to a manifold above the door. The air enters the firebox through a 34.0 cm × 1.6 cm ($13^3/_8$ in × $^5/_8$ in) opening above the glass door, washing the door as it enters. The primary air which enters the stove through a 2.5 cm (1 in) diameter pipe is routed to a manifold just inside and level with the firebox entrance. Both primary air intake ports are regulated by one wedge-shaped slide plate with one elliptical opening in it. Both "Super 27" woodstoves in the study were equipped with factory-installed electric fans.

5. Blaze King "King" (non-catalytic), Energy King "King" (non-catalytic), Energy King "Princess":

The Blaze King "King" and the Energy King "King" are virtually identical woodstoves. The "Princess" is a smaller version of the "King." Each of the three stove models are constructed of welded steel plate. The usable firebox volume of the "King" is 0.1274 m^3 (4.50 ft^3), and the usable firebox volume of the "Princess" is 0.0906 m^3 (3.20 ft^3). The primary combustion air intake on each of these stoves is thermostatically controlled. Primary combustion air enters the firebox through a rectangular opening located at the base of the back wall. The air flow is directed through the firebox and out of a hole in a plate located at the top of the firebox. The flow is then routed between the plate and the top of the stove and out the 20.3 cm (8 in) diameter top-exit flue collar.

B. New Woodheat Technology (Stage 2)

1. Double Wall Flue Pipe:

Two styles of double wall flue pipe were used in the study. The original objective of the study was to install sealed double wall flue pipe. However, due to a misunderstanding with a local supplier of flue pipe, vented double wall pipe was initially installed in two homes. The first style evaluated in each of the two study homes was manufactured by Security Chimneys Ltd., and had rectangular vents in the outer wall at either end of each 76 cm (30 in) section of pipe. The second style of flue pipe used in the study was manufactured by James A. Ryder Manufacturing and had a dead air space between the pipe walls. The double-wall pipe replaced single wall systems that were in place between the stove flue collar and the wall or ceiling thimble.

2. Low Emission Non-Catalytic Woodstoves:

One model of a low emission non-catalytic woodstove was evaluated in the study. The following stove model was used in the study:

Osburn "Imperial 2000" (Manufactured by Osburn Industries):

The "Imperial 2000" had the smallest usable firebox volume of the woodstoves evaluated in this study—0.0436 m^3 (1.54 ft^3). The stove has a steel inner firebox which is surrounded by a 1.3 cm ($^1/_2$ in) ceramic insulation blanket on the sides, rear, and bottom. The inner assembly is enclosed by a steel outer firebox which is shielded by a sheet metal convection air jacket on the sides and rear. The top of the firebox is a baffle with a 48.3 cm × 4.4 cm (19 in × $1^3/_4$ in) opening at the front of the firebox for exiting flue gas.

Primary combustion air enters through two 3.2 cm × 12.1 cm ($1^1/_4$ in × $4^3/_4$ in) slots in the rear of the pedestal base. The primary air travels through a 15.2 cm (6 in) diameter hole in the outer firebox to a 15.2 cm × 5.1 cm (2 in × 6 in) duct in the space between the inner and outer fireboxes. The duct acts as a manifold and directs the air to both the sides and rear of the stove. The side air goes up two risers to the top of the stove, across and above the door, and enters the firebox flowing down the inside face of the glass, serving as an air wash. The rear air flows along the bottom of the stove, up the back, and enters the firebox through a 45.7 cm × 1.3 cm (18 in × $^1/_2$ in) opening at the top rear.

The primary combustion air is controlled by a 7.6 cm (3 in) diameter slide gate. By-products of combustion exit the firebox by traveling toward the front of the firebox, around the baffle plate, and out the 15.2 cm (6 in) diameter top-exit flue collar.

The "Imperial 2000" stoves used in the study were equipped with factory-installed electric fans. Because of its relatively small firebox, logs had to be cut into 35 cm (14 in) lengths. A schematic of the cross-sectional area of this stove is included in Appendix D.

3. Catalytic "Add-on" Retrofits:

Two models of catalytic retrofits were monitored in the study. The catalytic retrofits evaluated in this study included:

a. Nu-Tec Catalytic Retrofit (Manufactured by NU-TEC Incorporated):

The Nu-Tec is a stack add-on style of catalytic retrofit. The device is designed to be mounted directly on the flue collar of the woodstove and substituted for a section of stovepipe. The base and top of the unit have 20.3 cm (8 in) mounting collars. The cast iron unit housing is 20.3 cm (8 in) in diameter and 15.2 cm (6 in) long.

The Nu-Tec uses an Applied Energy Systems Model No. 54152020 catalyst measuring 13.7 cm (5.4 in) in diameter by 3.8 cm (1.5 in) thick, and contains 3.1 cells per square centimeter (20 cells per square inch). The catalyst is mounted in a cast iron holder that rotates 90 degrees on a pivot point located in the center of the unit housing. In the engaged position the catalyst is perpendicular to the flow and all flue gas is routed through it. In the bypass position the catalyst is parallel to the flow and the flue gas is routed around the catalyst. A schematic of this device is in Appendix D.

b. Uni-Com Catalytic Damper (Manufactured by Dominion Manufacturing, Inc.):

The Uni-Com is also a stack add-on style of catalytic retrofit. The base and top of the unit have 20.3 cm (8 in) mounting collars. The steel unit housing measures 28.6 cm ($11^1/_4$ in) in diameter by 27.0 cm ($10^5/_8$ in) long. The Uni-Com contained a Corning Glass Model 6000 catalyst measuring 14.4 cm (5.66 in) in diameter by 7.6 cm (3 in) thick, and contains 2.5 cells per square centimeter (16 cells per square inch).

The catalyst action is controlled by a lever which raises and lowers the catalyst in the unit housing. In the engaged position the catalyst seats in the bottom of the unit housing and flue gas is routed through it. In the bypass position the control lever linkage lifts the catalyst from the seat into the afterburner assembly housing. The afterburner assembly consists of a 14.6 cm ($5^3/_4$ in) diameter by 1.9 cm ($^3/_4$ in) ceramic disk supported by a steel casing. The ceramic disk acts as a heat sink and helps to retain heat in the vicinity of the catalyst. In the bypass mode flue gas is routed around the underside of the catalyst. There is a bypass lever stop welded to the unit housing that allows the catalyst to be placed in a partially bypassed position. In this position the catalyst does not quite seat in the base of the unit, and flue gas is routed both through and around the catalyst. A schematic of this device is in Appendix D.

4. Integral Catalytic Woodstoves:

Two models of integral catalytic woodstoves were monitored in the study. The integral catalytic woodstoves which were evaluated include:

a. Blaze King "King" (Manufactured by Blaze King, Canada, Ltd.):

The Blaze King "King" was the largest integral catalytic woodstove evaluated in the study. The "King" has a usable firebox volume of 0.1274 m^3 (4.50 ft^3). The stove is constructed of welded steel plate and could accommodate firewood up to 56 cm (22 in) in length.

Primary and secondary combustion air enter the unit through two 3.8 cm × 2.5 cm ($1^1/_2$ in × 1 in) rectangular openings located at the rear bottom of the unit. The primary air is routed to the top of the rear stove wall and is restricted by a flap which is thermostatically controlled with a bimetallic coil. The primary air flows downward and enters the firebox via a 11.4 cm × 3.8 cm

($4^1/_2$ in × $1^1/_2$ in) rectangular opening located at the center of the rear firebox wall, 5.1 cm (2 in) above the hearth. Secondary air is diverted from the intake into two 2.9 cm ($1^1/_8$ in) OD tubes which enter the firebox and extend to the top center directly below the catalyst assembly. The secondary air exits in a 0.6 cm ($^1/_4$ in) airspace between two oval steel plates. The plates have a short diameter of 5.1 cm (2 in) and a long diameter of 10.2 cm (4 in).

A tertiary air intake is located at the front of the left side of the stove. Tertiary air enters the unit through a 1.6 cm ($^5/_8$ in) ID tube and is routed to a location directly above the catalyst. The tertiary air enters the gas stream through two 1.0 ($^3/_8$ in) diameter holes cut into the intake tube.

The oval-shaped catalyst used in the stove was manufactured by Matsushita Battery Co. of Japan (distributed by Technical Glass Products) with a long diameter of 21.9 cm ($8^5/_8$ in), a short diameter of 18.1 cm ($7^1/_8$ in), and a thickness of 5.1 cm (2 in). The catalyst contains 2.5 cells per square centimeter (16 cells per square inch).

When the fuel loading door is unlatched the bypass damper door may be opened. In the bypass position flue gas exits through the 22.9 cm × 15.2 cm (9 in × 6 in) bypass opening located at the top rear of the firebox and out the 20.3 cm (8 in) top-exit flue collar. When the fuel loading door is closed, the bypass door is closed automatically by a spring-loaded push rod. In the engaged position flue gas is routed to the top center of the firebox where it is mixed with secondary combustion air, passes through the catalyst, is mixed with tertiary air, and exits out the 20.3 cm (8 in) diameter top-exit flue collar.

Convection air is drawn into two convection air manifolds by two electric fans located on the bottom of the rear stove wall. The convection air travels from the manifold up the rear wall of the stove and to a duct located between the top of the firebox and the top of the stove. The convection air exits through two 11.4 cm × 4.4 cm ($4^1/_2$ in × $1^3/_4$ in) openings located at both top corners of the front of the stove. A schematic of this stove is found in Appendix D.

b. Burning Log "Turbo 10" (Manufactured by Burning Log Fireplace Specialists, Ltd.):

The "Turbo 10" has a usable firebox volume of 0.0651 m^3 (2.30 ft^3). The plate steel firebox has a sheet metal jacket on the top and rear of the stove and a thin steel framework that supports six 20.0 cm × 20.0 cm ($7^7/_8$ in × $7^7/_8$ in) ceramic tiles on either side. The manufacturer's instructions indicate that the stove will accommodate log lengths up to 46 cm (18 in).

Primary combustion air enters the unit in each lower front corner through the primary air manifolds. The primary air is then routed to a channel above the fuel loading door where it washes the glass door as it is introduced into the firebox. Primary air is regulated by a rectangular damper flap located in the channel above the door that is thermostatically controlled by a bimetallic coil.

Secondary combustion air enters at the lower rear corners of the firebox on the rear stove wall. The secondary air is conducted via a 3.5 cm ($1^3/_8$ in) OD U-shaped tube. The two legs of the "U" run along either side of the firebox and converge just in front of the catalysts, which are mounted vertically at the top front of the firebox. The secondary air exits the tube through two slots cut in the U-shaped tube. The two slots measure 7.6 cm × 1.3 cm and 12.7 cm × 1.3 cm (5 in × $^1/_2$ in and 7 in × $^1/_2$ in).

Two Corning Model 6000 rectangular-shaped catalysts are used in the "Turbo 10." The catalysts each measure 17.8 cm (7 in) long by 5.4 cm ($2^1/_8$ in) wide by 5.1 cm (2 in) deep. The catalysts are mounted with the long axis horizontal alongside each other at the top front of the firebox between the top of the firebox and the top of the stove.

In the catalyst bypass mode, flue gas exits the firebox via a 15.6 cm ($6^1/_8$ in) diameter opening located at the top rear center of the firebox and in line with the 15.2 cm (6 in) flue collar. In the engaged mode, the flue gas is routed toward the top front of the firebox where secondary air is introduced. The gas then is routed through the catalyst and directly out the flue collar. A schematic of this stove is found in Appendix D.

VI. RESULTS

A. General Notes

Tables 1–A through 14–B provide stove operation information, particulate emission rates, and estimated overall efficiency for each home in the study. The following are notes that pertain to the data presented in the tables:

- Data presented in the tables was compiled during the days that the AWES units were sampling. Sampling periods for homes W01 through W07 and homes W08 through W14 occurred on alternate weeks.
- Occasional sensor malfunctions resulted in some lost data. Missing data is indicated by the absence of data in the tables for the sampling period during which the malfunction occurred.
- Fuel moisture contents presented are on a dry basis.
- Overall thermal efficiencies were calculated using a modified version of an overall efficiency calculation method developed for the Condar sampling system.[7]

The overall data recovery rate for this project was 92.8%. This value was derived by assigning one point to each emission sample (either before-catalyst or after-catalyst) and each wood weight/flue temperature data set for individual sampling periods. There were a total of 279 data points possible for the study (153 possible emission samples and 126 possible wood weight/flue temperature data sets). A total of 20 data points were lost due to sensor malfunctions.

HOME CODE: W01

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days^a	Alternative Heat Use (Hours)	Stove Operation (%)^b	Catalyst Operation (%)^c	Fuel Type^d	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
RSF "65" (Conventional)	1	24/11/86-30/11/86	193.3	0.0	96.9%	N/A	100% FKLP	16.8	314.9	1.93	45.6%
	2	08/12/86-14/12/86	131.5	0.0	87.8%	N/A	100% FKLP	14.5	194.1	1.32	45.1%
	4	05/01/87-11/01/87	141.1	2.2	97.9%	N/A	50% SLP 50% FKLP	48.0 13.9	206.9	1.26	41.2%
with Security Vented Double-Wall Flue Pipe	5	02/02/87-08/02/87	161.1	N/A	100.0%	N/A	100% FKLP	13.5	256.9	1.53	47.4%
	6	16/02/87-22/02/87	148.6	0.0	94.8%	N/A	100% FKLP	15.2	251.3	1.58	48.0%
with James A. Ryder Air-Insulated Double-Wall Flue Pipe	7	02/03/87-08/03/87	301.2	9.5	99.0%	N/A	100% FKLP	15.8	357.4	2.15	55.7%
	8	16/03/87-22/03/87	165.3	13.1	50.7%	N/A	75% SLP 25% FKLP	15.6 12.6	95.7	1.12	43.9%
	9	30/03/87-05/04/87	119.9	9.4	49.0%	N/A	100% SLP	15.6	65.3	0.79	46.9%

Fueling, Burn Rate, and Efficiency Data

Table 1A

HOME CODE: W01

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3	
			Emission Rate	{P} [A]^c	Emission Rate	{P} [A]^c	Emission Rate	{P} [A]^c	Concen-tration	{P} [A]^c
RSF "65" (Conventional)	1	24/11/86-30/11/86	49.8	{±12.7} [±16.6]	25.8	{±5.2} [±8.0]	2.8	{±0.6} [±0.9]	1.74	{±0.22} [±0.29]
	2	08/12/86-14/12/86	30.4	{±9.2} [±11.8]	23.1	{±5.8} [±8.5]	2.6	{±0.7} [±1.0]	1.00	{±0.14} [±0.15]
	4	05/01/87-11/01/87	25.8	{±8.6} [±11.2]	20.5	{±5.7} [±8.5]	2.5	{±0.7} [±1.1]	0.77	{±0.12} [±0.13]
with Security Vented Double-Wall Flue Pipe	5	02/02/87-08/02/87	33.9	{±8.7} [±11.5]	22.2	{±4.5} [±7.0]	2.4	{±0.5} [±0.8]	1.32	{±0.16} [±0.20]
	6	16/02/87-22/02/87	28.1	{±8.1} [±10.3]	17.8	{±4.2} [±6.1]	1.9	{±0.5} [±0.7]	0.90	{±0.12} [±0.14]
with James A. Ryder Air-Insulated Double-Wall Flue Pipe	7	02/03/87-08/03/87	22.9	{±6.0} [±7.2]	10.7	{±2.2} [±3.1]	1.0	{±0.2} [±0.3]	0.77	{±0.11} [±0.12]
	8	16/03/87-22/03/87	25.5	{±9.4} [±11.7]	22.7	{±7.1} [±9.9]	2.6	{±0.9} [±1.2]	0.92	{±0.18} [±0.20]
	9	30/03/87-05/04/87	18.0	{±6.4} [±8.0]	22.7	{±6.9} [±9.6]	2.4	{±0.8} [±1.1]	0.88	{±0.16} [±0.17]

Particulate Emission Rate Data
Table 1B

HOME CODE: W02

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
RSF "65" (Conventional)	1	24/11/86-30/11/86	193.3	37.7	97.4%	N/A	100% FKLP	17.2	236.6	1.45	48.2%
	2(f)	12/12/86-15/12/86	75.9	2.1	99.9%	N/A	100% FKLP	19.8	77.9	1.29	59.1%
	3	22/12/86-28/12/86	183.2	7.9	100.0%	N/A	100% SS	28.9	245.5	1.46	56.6%
	4	05/01/87-11/01/87	141.1	9.5	100.0%	N/A	50% SS 50% FKLP	41.8 15.1	150.9	0.90	53.7%(i)
with Nu-Tec (Catalytic "Add-on" Retrofit)	5	02/02/87-08/02/87	161.1	2.1	100.0%	12.2%	100% FKLP	18.0	202.7	1.21	42.9%
	6	16/02/87-22/02/87	148.6	2.7	99.7%	6.7%	100% FKLP	21.8	144.7	0.86	(g)
RSF "65" (Conventional)	8	16/03/87-22/03/87	165.3	2.9	94.5%	N/A	95% SS 5% FKLP	33.0 17.5	118.7	0.75	41.9%
	9	30/03/87-05/04/87	119.9	1.7	98.5%	N/A	100% SS	24.1	92.9	0.56	50.2%

Fueling, Burn Rate, and Efficiency Data

Table 2A

HOME CODE: W02

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Sampling Location	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3		Percent Emissions Reduction[h]
				Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Concen-tration	{P} [A][e]	
RSF "65" (Conventional)	1	24/11/86- 30/11/86	Flue Collar	28.9	{±7.4} [±9.3]	20.0	{±4.0} [±6.0]	2.1	{±0.5} [±0.7]	1.18	{±0.14} [±0.16]	N/A
	2[f]	12/12/86- 15/12/86	Flue Collar	17.2	{±4.8} [±6.0]	13.3	{±3.0} [±4.3]	1.1	{±0.3} [±0.4]	0.79	{±0.11} [±0.13]	N/A
	3	22/12/86- 28/12/86	Flue Collar	17.3	{±5.2} [±6.3]	11.8	{±2.9} [±4.0]	1.0	{±0.3} [±0.4]	0.59	{±0.09} [±0.09]	N/A
	4[i]	05/01/87- 11/01/87	Flue Collar	11.5	{±3.8} [±4.7]	12.8	{±3.5} [±5.0]	1.2	{±0.3} [±0.5]	0.56	{±0.09} [±0.10]	N/A
with Nu-Tec (Catalytic "Add-on" Retrofit)	5	02/02/87- 08/02/87	Before Catalyst	50.3	{±12.0} [±16.5]	41.7	{±7.7} [±12.7]	5.3	{±1.1} [±1.7]	2.76	{±0.31} [±0.46]	27.2%
			After Catalyst	36.6	{±10.0} [±13.5]	30.3	{±6.7} [±10.5]	3.6	{±0.9} [±1.3]	1.55	{±0.20} [±0.27]	
	6	16/02/87- 22/02/87	Before Catalyst	38.5	{±10.0} [±13.9]	44.5	{±9.2} [±15.1]	5.4	{±1.2} [±1.9]	2.09	{±0.23} [±0.33]	N/A[g]
RSF "65" (Conventional)	8	16/03/87- 22/03/87-	Flue Collar	17.7	{±6.5} [±8.8]	23.6	{±7.4} [±11.3]	2.8	{±0.9} [±1.4]	0.71	{±0.11} [±0.13]	N/A
	9	30/03/87- 05/04/87-	Flue Collar	13.1	{±4.3} [±5.8]	23.3	{±6.4} [±9.9]	2.3	{±0.7} [±1.0]	0.87	{±0.13} [±0.16]	N/A

Particulate Emission Rate Data
Table 2B

HOME CODE: W03

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
Fisher "Grandma Bear" (Conventional)	1	24/11/86-30/11/86	193.3	0.0	100.0%	N/A	100% FKLP	15.4	198.7	1.18	62.5%
	2	08/12/86-14/12/86	131.5	0.0	100.0%	N/A	100% FKLP	14.3	174.7	1.04	57.3%
	3	22/12/86-28/12/86	183.2	0.0	99.6%	N/A	99% SS 1% FKLP	40.4 17.3	218.4	1.31	50.8%(j)
	4	05/01/87-11/01/87	141.1	0.0	99.3%	N/A	50% SS 50% FKLP	40.1 14.6	239.7	1.44	54.8%
Burning Log "Turbo 10" (Integral Catalytic)	5	02/02/87-08/02/87	161.1	0.0	99.6%	77.2%	100% FKLP	16.0	164.9	0.99	54.7%
	6	16/02/87-22/02/87	148.6	0.0	99.1%	66.6%	100% FKLP	15.2	175.3	1.05	53.4%
	7	02/03/87-08/03/87	301.2	0.0	100.0%	82.6%	100% FKLP	17.6	213.4	1.27	60.5%
	8	16/03/87-22/03/87	165.3	0.0	100.0%	68.2%	80% SS 20% FKLP	32.7 13.6	185.8	1.11	57.7%
	9	30/03/87-05/04/87	119.9	0.0	90.3%	53.0%	100% SS	30.7	130.0	0.86	51.2%

Fueling, Burn Rate, and Efficiency Data

Table 3A

HOME CODE: W03

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Sampling Location	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3		Percent Emissions Reduction[h]
				Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Concen-tration	{P} [A][e]	
Fisher "Grandma Bear" (Conventional)	1	24/11/86-30/11/86	Flue Collar	5.7	{±1.6} [±1.6]	4.8	{±1.1} [±1.3]	0.4	{±0.1} [±0.1]	0.39	{±0.07} [±0.06]	N/A
	2	08/12/86-14/12/86	Flue Collar	8.6	{±2.6} [±2.9]	8.3	{±2.0} [±2.6]	0.7	{±0.2} [±0.2]	0.48	{±0.08} [±0.07]	N/A
	3(i)	22/12/86-28/12/86	Flue Collar	13.3	{±4.2} [±4.7]	10.2	{±2.4} [±3.1]	1.0	{±0.3} [±0.3]	0.55	{±0.08} [±0.07]	N/A
	4	05/01/87-11/01/87	Flue Collar	10.1	{±3.3} [±3.7]	7.0	{±1.9} [±2.4]	0.6	{±0.2} [±0.2]	0.41	{±0.07} [±0.07]	N/A
Burning Log "Turbo 10" (Integral Catalytic)	5	02/02/87-08/02/87	Before Catalyst	25.8	{±6.1} [±7.7]	26.2	{±4.8} [±7.2]	2.9	{±0.6} [±0.9]	1.85	{±0.21} [±0.28]	66.7%
			After Catalyst	8.6	{±2.3} [±2.6]	8.7	{±1.9} [±2.4]	0.8	{±0.2} [±0.2]	0.56	{±0.08} [±0.08]	
	6	16/02/87-22/02/87	Before Catalyst	22.7	{±5.6} [±7.1]	21.6	{±4.2} [±6.3]	2.3	{±0.5} [±0.7]	1.42	{±0.17} [±0.22]	53.7%
			After Catalyst	10.5	{±3.1} [±3.7]	9.9	{±2.4} [±3.3]	0.9	{±0.2} [±0.3]	0.58	{±0.09} [±0.10]	
	7	02/03/87-08/03/87	Before Catalyst	15.3	{±3.4} [±4.0]	12.1	{±2.1} [±2.9]	1.1	{±0.2} [±0.3]	1.13	{±0.13} [±0.16]	59.5%
			After Catalyst	6.2	{±1.8} [±1.9]	4.9	{±1.2} [±1.4]	0.4	{±0.1} [±0.1]	0.41	{±0.07} [±0.02]	
	8	16/03/87-22/03/87	Before Catalyst	20.1	{±4.8} [±6.0]	18.2	{±3.3} [±5.0]	1.8	{±0.4} [±0.5]	1.29	{±0.15} [±0.19]	55.2%
			After Catalyst	9.0	{±2.5} [±2.9]	8.1	{±1.8} [±2.4]	0.7	{±0.2} [±0.2]	0.55	{±0.09} [±0.09]	
	9	30/03/87-05/04/87	Before Catalyst	16.2	{±4.0} [±5.0]	18.9	{±3.6} [±5.4]	1.9	{±0.4} [±0.6]	1.22	{±0.15} [±0.18]	26.5%
			After Catalyst	11.9	{±3.3} [±3.9]	13.9	{±3.1} [±4.3]	1.3	{±0.3} [±0.4]	0.76	{±0.10} [±0.11]	

Particulate Emission Rate Data
Table 3B

HOME CODE: W04

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
Sears "Automatic" (Conventional)	1	24/11/86-30/11/86	193.3	0.0	100.0%	N/A	100% FKLP	16.6	319.6	1.90	41.7%
	2	08/12/86-14/12/86	131.5	0.0	98.5%	N/A	100% FKLP	15.8	207.2	1.25	41.9%
	3	22/12/86-28/12/86	183.2	0.0	100.0%	N/A	90% SS 10% FKLP	30.2 11.7	336.6	2.01	39.8%
	4	05/01/87-11/01/87	141.1	0.0	99.7%	N/A	50% SS 50% FKLP	25.4 18.3	313.6	1.87	44.9%
Osburn "Imperial 2000" (Low Emission Non-Catalytic)	5	02/02/87-08/02/87	161.1	0.7	100.0%	N/A	100% FKLP	12.7	216.3	1.29	53.8%
	6	16/02/87-22/02/87	148.6	0.4	100.0%	N/A	100% FKLP	15.3	181.0	1.08	49.3%
	7	02/03/87-08/03/87	301.2	23.9	100.0%	N/A	100% FKLP	13.8	254.3	1.51	51.0%
	8	16/03/87-22/03/87	165.3	1.0	100.0%	N/A	50% SS 50% FKLP	31.9 15.6	200.7	1.20	45.8%
	9	30/03/87-05/04/87	119.9	1.1	100.0%	N/A	50% SS 50% FKLP	16.2 16.2	185.9	1.11	54.6%

Fueling, Burn Rate, and Efficiency Data

Table 4A

HOME CODE: W04

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3	
			Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Concentration	{P} [A][e]
Sears "Automatic" (Conventional)	1	24/11/86-30/11/86	40.7	{±10.4} [±13.2]	21.4	{±4.3} [±6.5]	2.6	{±0.6} [±0.8]	1.24	{±0.14} [±0.17]
	2	08/12/86-14/12/86	29.2	{±8.0} [±10.7]	23.3	{±5.2} [±8.0]	2.8	{±0.7} [±1.0]	1.18	{±0.15} [±0.19]
	3	22/12/86-28/12/86	35.7	{±10.2} [±12.8]	17.8	{±4.1} [±6.0]	2.2	{±0.6} [±0.8]	0.82	{±0.11} [±0.11]
	4	05/01/87-11/01/87	26.3	{±7.7} [±9.5]	14.1	{±3.4} [±4.8]	1.6	{±0.4} [±0.6]	0.67	{±0.09} [±0.10]
Osburn "Imperial 2000" (Low-Emission Non-Catalytic)	5	02/02/87-08/02/87	10.5	{±2.9} [±3.5]	8.1	{±1.8} [±2.5]	0.8	{±0.2} [±0.3]	0.66	{±0.10} [±0.12]
	6	16/02/87-22/02/87	9.2	{±2.7} [±3.3]	8.5	{±2.1} [±2.8]	0.9	{±0.2} [±0.3]	0.54	{±0.09} [±0.10]
	7	02/03/87-08/03/87	5.3	{±2.2} [±2.1]	3.5	{±1.3} [±1.3]	0.3	{±0.1} [±0.1]	0.22	{±0.06} [±0.05]
	8	16/03/87-22/03/87	12.8	{±3.5} [±4.1]	10.7	{±2.3} [±3.2]	1.2	{±0.3} [±0.4]	0.67	{±0.09} [±0.10]
	9	30/03/87-05/04/87	10.3	{±2.9} [±3.5]	9.3	{±2.1} [±3.0]	0.9	{±0.2} [±0.3]	0.67	{±0.10} [±0.12]

Particulate Emission Rate Data
Table 4B

HOME CODE: W05

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days^a	Alternative Heat Use (Hours)	Stove Operation (%)^b	Catalyst Operation (%)^c	Fuel Type^d	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
Acorn "Ranger" (Conventional)	1	24/11/86-30/11/86	193.3	0.0	91.3%	N/A	50% FKLP 50% SLP	17.9 19.2	255.8	1.67	55.7%
	2	08/12/86-14/12/86	131.5	0.0	78.0%	N/A	100% FKLP	16.1	208.4	1.59	42.8%
	3	22/12/86-28/12/86	183.2	0.0	72.6%	N/A	90% SS 10% FKLP	43.4 13.7	200.0	1.64	55.7%
	4	05/01/87-11/01/87	141.1	0.0	79.1%	N/A	50% SS 50% FKLP	30.7 13.6	229.5	1.73	44.4%
with Uni-Com (Catalytic "Add-on" Retrofit)	5	02/02/87-08/02/87	161.1	0.0	64.4%	35.7%	100% FKLP	13.8	179.2	1.66	64.2%(j)
	6	16/02/87-22/02/87	148.6	0.0	34.4%	48.1%	100% FKLP	14.6	84.9	1.47	58.6%
	7	02/03/87-08/03/87	301.2	0.0	92.0%	69.5%	100% FKLP	14.4	266.9	1.73	(g)
	8	16/03/87-22/03/87	165.3	0.0	59.1%	53.9%	95% SS 5% FKLP	32.4 14.4	135.9	1.37	59.5%
	9	30/03/87-05/04/87	119.9	0.0	31.5%	41.8%	100% FKLP	28.3	53.8	1.02	(g)

Fueling, Burn Rate, and Efficiency Data

Table 5A

HOME CODE: W05

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Sampling Location	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3		Percent Emissions Reduction[h]
				Emission Rate	{P} [A][c]	Emission Rate	{P} [A][c]	Emission Rate	{P} [A][c]	Concentration	{P} [A][c]	
Acorn "Ranger" (Conventional)	1	24/11/86-30/11/86	Flue Collar	10.9	{±3.6} [±3.8]	6.5	{±1.8} [±2.1]	0.6	{±0.2} [±0.2]	0.40	{±0.08} [±0.07]	N/A
	2	08/12/86-14/12/86	Flue Collar	14.1	{±6.2} [±6.4]	8.9	{±3.4} [±3.8]	1.0	{±0.4} [±0.5]	0.30	{±0.08} [±0.05]	N/A
	3	22/12/86-27/12/86	Flue Collar	13.4	{±4.5} [±4.3]	8.1	{±2.1} [±2.2]	0.7	{±0.2} [±0.2]	0.53	{±0.09} [±0.07]	N/A
	4	05/01/87-11/01/87	Flue Collar	18.7	{±7.4} [±8.4]	10.8	{±3.7} [±4.6]	1.2	{±0.4} [±0.5]	0.41	{±0.09} [±0.08]	N/A
with Uni-Com (Catalytic "Add-on" Retrofit)	5	02/02/87-08/02/87	Before Catalyst	16.8	{±4.3} [±4.6]	10.1	{±2.1} [±2.6]	0.8	{±0.2} [±0.2]	0.88	{±0.13} [±0.13]	66.7%
			After Catalyst(j)	5.6	{±2.9} [±2.2]	3.4	{±1.6} [±1.2]	0.3	{±0.1} [±0.1]	0.20	{±0.08} [±0.04]	
	6	16/02/87-22/02/87	Before Catalyst	16.5	{±6.7} [±6.7]	11.2	{±4.0} [±4.3]	1.0	{±0.4} [±0.4]	0.62	{±0.17} [±0.14]	14.5%
			After Catalyst	14.1	{±5.4} [±4.8]	9.6	{±3.2} [±3.1]	0.8	{±0.3} [±0.3]	0.59	{±0.15} [±0.10]	
	8	16/03/87-22/03/87	Before Catalyst	21.3	{±6.4} [±7.5]	15.6	{±3.8} [±5.2]	1.5	{±0.4} [±0.5]	0.92	{±0.15} [±0.17]	47.9%
			After Catalyst	11.1	{±3.6} [±3.4]	8.1	{±2.2} [±2.3]	0.7	{±0.2} [±0.2]	0.53	{±0.10} [±0.08]	
	9	30/03/87-05/04/87	Before Catalyst	9.5	{±4.0} [±3.6]	9.3	{±3.4} [±3.3]	0.8	{±0.3} [±0.3]	0.57	{±0.16} [±0.12]	N/A(g)

Particulate Emission Rate Data
Table 5B

HOME CODE: W06

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
Energy King "Princess" (Conventional)	1	24/11/86-30/11/86	193.3	0.0	100.0%	N/A	100% FKLP	16.2	195.2	1.16	53.1%
	2	08/12/86-14/12/86	131.5	1.8	99.9%	N/A	100% FKLP	21.8	193.6	1.06	(g)
	3	22/12/86-28/12/86	183.2	3.0	99.6%	N/A	100% SS	29.5	205.5	1.23	54.8%
	4	05/01/87-11/01/87	141.1	0.6	100.0%	N/A	100% SS	19.8	219.6	1.31	59.9%
Pacific Energy Systems (Low Emission Non-Catalytic)	5	02/02/87-08/02/87	161.1	0.7	99.3%	N/A	100% FKLP	16.6	184.7	1.11	57.0%(j)
	6	16/02/87-22/02/87	148.6	1.7	88.8%	N/A	100% FKLP	16.5	114.2	0.77	46.3%(j)
	7	02/03/87-08/03/87	301.2	6.6	100.0%	N/A	100% FKLP	19.4	190.9	1.14	59.4%
	8	16/03/87-22/03/87	165.3	1.8	95.1%	N/A	90% SS 10% FKLP	40.1 22.2	106.1	0.66	54.0%
	9	30/03/87-05/04/87	119.9	0.4	72.1%	N/A	100% SS	37.9	73.5	0.61	55.5%

Fueling, Burn Rate, and Efficiency Data

Table 6A

HOME CODE: W06

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3	
			Emission Rate	{P} $[A]^e$	Emission Rate	{P} $[A]^e$	Emission Rate	{P} $[A]^e$	Concentration	{P} $[A]^e$
Energy King "Princess" (Conventional)	1	24/11/86-30/11/86	19.2	{±4.6} [±5.8]	16.5	{±3.1} [±4.6]	1.6	{±0.3} [±0.5]	1.22	{±0.14} [±0.18]
	3	22/12/86-28/12/86	18.8	{±4.4} [±5.4]	15.3	{±2.8} [±4.1]	1.4	{±0.3} [±0.4]	1.26	{±0.15} [±0.19]
	4	05/01/87-11/01/87	15.7	{±3.8} [±4.8]	12.0	{±2.3} [±3.4]	1.0	{±0.2} [±0.3]	1.13	{±0.15} [±0.20]
Pacific Energy Systems (Low Emission Non-Catalytic)	$5^{(j)}$	02/02/87-08/02/87	19.1	{±4.3} [±5.4]	17.2	{±3.0} [±4.5]	1.5	{±0.3} [±0.4]	1.43	{±0.16} [±0.20]
	$6^{(j)}$	16/02/87-22/02/87	20.9	{±5.4} [±7.1]	27.4	{±5.6} [±8.7]	3.0	{±0.7} [±1.0]	1.53	{±0.18} [±0.23]
	7	02/03/87-08/03/87	16.1	{±4.0} [±5.1]	14.1	{±2.7} [±4.1]	1.2	{±0.3} [±0.4]	1.21	{±0.16} [±0.22]
	8	16/03/87-22/03/87	12.6	{±3.7} [±4.6]	18.9	{±3.9} [±6.1]	1.7	{±0.4} [±0.6]	1.28	{±0.17} [±0.23]
	9	30/03/87-05/04/87	10.0	{±3.0} [±3.4]	16.5	{±3.5} [±4.9]	1.5	{±0.3} [±0.5]	1.10	{±0.15} [±0.17]

Particulate Emission Rate Data
Table 6B

HOME CODE: W07

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
Blaze King "King" (Conventional)	1	24/11/86-30/11/86	193.3	0.0	92.2%	N/A	100% FKLP	15.5	352.4	2.28	(g)
	2	08/12/86-14/12/86	131.5	0.0	81.7%	N/A	100% FKLP	20.1	257.6	1.88	51.6%
	3	22/12/86-28/12/86	183.2	0.0	95.7%	N/A	80% SS 20% FKLP	21.2 18.7	341.0	2.12	57.0%
	4	05/01/87-11/01/87	141.1	0.0	84.6%	N/A	50% SS 50% FKLP	21.2 19.1	364.9	2.57	42.7%(j)
Blaze King "King" (Integral Catalytic)	5	02/02/87-08/02/87	161.1	0.0	98.2%	84.5%	100% FKLP	15.2	283.2	1.72	64.2%
	6	16/02/87-22/02/87	148.6	0.0	94.0%	87.2%	100% FKLP	17.0	256.5	1.62	69.9%
	8	16/03/87-22/03/87	165.3	0.0	100.0%	79.2%	80% SS 20% FKLP	32.7 13.6	309.9	1.85	57.0%
	9(k)	30/03/87-05/04/87	73.0	0.0	90.2%	58.6%	60% SS 40% FKLP	32.7 20.8	159.6	1.48	51.1%

Fueling, Burn Rate, and Efficiency Data

Table 7A

HOME CODE: W07

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Sampling Location	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3		Percent Emissions Reduction^h
				Emission Rate	{P} [A]^e	Emission Rate	{P} [A]^e	Emission Rate	{P} [A]^e	Concen-tration	{P} [A]^e	
Blaze King "King" (Conventional)	2	08/12/86-14/12/86	Flue Collar	32.8	{±7.5} [±9.0]	17.5	{±3.0} [±4.4]	1.7	{±0.3} [±0.5]	1.58	{±0.18} [±0.22]	N/A
	3	22/12/86-28/12/86	Flue Collar	21.5	{±5.1} [±6.1]	10.1	{±1.9} [±2.6]	0.9	{±0.2} [±0.2]	0.99	{±0.13} [±0.15]	N/A
	4$^{(j)}$	05/01/87-11/01/87	Flue Collar	35.0	{±10.3} [±12.6]	13.6	{±3.3} [±4.6]	1.6	{±0.4} [±0.6]	0.72	{±0.11} [±0.12]	N/A
Blaze King "King" (Integral Catalytic)	5	02/02/87-08/02/87	Before Catalyst	28.1	{±6.3} [±7.9]	16.4	{±2.8} [±4.2]	1.4	{±0.3} [±0.4]	1.44	{±0.16} {±0.22}	73.7%
			After Catalyst	7.4	{±2.8} [±2.6]	4.3	{±1.4} [±1.4]	0.3	{±0.1} [±0.1]	0.22	{±0.05} [±0.04]	
	6	16/02/87-22/02/87	Before Catalyst	25.0	{±5.4} [±6.3]	15.4	{±2.5} [±3.5]	1.3	{±0.2} [±0.3]	1.41	{±0.15} [±0.18]	70.0%
			After Catalyst	7.5	{±3.3} [±3.6]	4.6	{±1.8} [±2.1]	0.4	{±0.1} [±0.2]	0.22	{±0.07} [±0.06]	
	8	16/03/87-22/03/87	Before Catalyst	35.9	{±8.3} [±10.0]	19.4	{±3.4} [±5.0]	1.7	{±0.3} [±0.5]	1.68	{±0.20} [±0.26]	41.5%
			After Catalyst	21.0	{±5.9} [±7.0]	11.4	{±2.6} [±3.6]	1.0	{±0.2} [±0.3]	0.64	{±0.09} [±0.10]	
	9$^{(k)}$	30/03/87-05/04/87	Before Catalyst	27.3	{±7.5} [±8.6]	18.4	{±4.0} [±5.4]	1.7	{±0.4} [±0.5]	1.15	{±0.17} [±0.18]	7.0%
			After Catalyst	25.4	{±9.0} [±10.6]	17.2	{±5.1} [±6.8]	1.7	{±0.5} [±0.7]	0.70	{±0.14} [±0.13]	

Particulate Emission Rate Data
Table 7B

HOME CODE: W08

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
RSF "65" (Conventional)	1	01/12/86-07/12/86	190.6	1.9	98.7%	N/A	100% FKLP	16.9	273.1	1.65	(g)
	2	15/12/86-21/12/86	150.7	1.0	78.1%	N/A	100% FKLP	20.4	197.3	1.50	50.9%
	3	29/12/86-04/01/87	160.7	1.7	76.0%	N/A	100% SS	19.9	166.0	1.30	37.0%(j)
	4	12/01/87-18/01/87	238.9	3.0	99.8%	N/A	100% SS	32.4	317.7	1.90	44.0%
with Uni-Com (Catalytic "Add-on" Retrofit)	5	09/02/87-15/02/87	197.1	0.9	97.6%	18.9%	100% FKLP	19.6	190.8	1.16	(g)
	6	23/02/87-01/03/87	199.2	5.3	73.7%	39.6%	100% FKLP	15.8	167.0	1.58	57.1%
	7(f)	09/03/87-12/03/87	128.3	2.2	64.6%	59.9%	100% FKLP	16.4	94.5	1.78	56.0%
	8	23/03/87-29/03/87	127.3	2.6	45.5%	36.4%	100% SS	27.0	98.8	1.29	50.8%
	9	06/04/87-12/04/87	127.2	1.9	46.3%	46.5%	100% SS	26.1	84.8	1.09	50.2%

Fueling, Burn Rate, and Efficiency Data

Table 8A

HOME CODE: W08

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Sampling Location	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3		Percent Emissions Reduction[h]
				Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Concen-tration	{P} [A][e]	
RSF "65" (Conventional)	2	15/12/86-21/12/86	Flue Collar	22.5	{±7.2} [±8.8]	15.0	{±4.0} [±5.5]	1.5	{±0.4} [±0.6]	0.68	{±0.11} [±0.11]	N/A
	3(j)	29/12/87-04/01/87	Flue Collar	31.3	{±11.4} [±15.3]	24.1	{±7.5} [±11.2]	3.2	{±1.1} [±1.6]	0.75	{±0.12} [±0.14]	N/A
	4	12/01/87-18/01/87	Flue Collar	31.7	{±10.4} [±13.5]	16.7	{±4.6} [±6.8]	1.9	{±0.6} [±0.8]	0.66	{±0.10} [±0.12]	N/A
with Uni-Com (Catalytic "Add-on" Retrofit)	5	09/02/87-15/02/87	Before Catalyst	26.1	{±7.3} [±9.6]	22.4	{±5.0} [±7.7]	2.2	{±0.5} [±0.8]	1.13	{±0.15} [±0.19]	N/A(g)
	6	23/02/87-01/03/87	Before Catalyst	15.9	{±5.3} [±5.9]	10.1	{±2.9} [±3.5]	0.9	{±0.3} [±0.3]	0.56	{±0.11} [±0.11]	15.7%
			After Catalyst	13.4	{±4.5} [±4.5]	8.5	{±2.4} [±2.7]	0.7	{±0.2} [±0.3]	0.43	{±0.08} [±0.06]	
	7(f)	09/03/87-12/03/87	Before Catalyst	36.1	{±11.3} [±12.1]	20.3	{±5.3} [±6.3]	2.2	{±0.6} [±0.7]	1.15	{±0.20} [±0.17]	72.3%
			After Catalyst	10.0	{±5.8} [±3.8]	5.6	{±3.0} [±2.0]	0.5	{±0.3} [±0.2]	0.30	{±0.13} [±0.06]	
	8	23/03/87-29/03/87	Before Catalyst	31.2	{±10.3} [±12.1]	24.1	{±6.6} [±8.9]	2.7	{±0.8} [±1.1]	1.01	{±0.17} [±0.16]	53.2%
			After Catalyst	14.6	{±5.8} [±5.8]	11.3	{±3.9} [±4.2]	1.1	{±0.4} [±0.4]	0.45	{±0.10} [±0.07]	
	9	06/04/87-12/04/87	Before Catalyst	28.7	{±8.2} [±9.7]	26.3	{±6.1} [±8.3]	2.8	{±0.7} [±0.9]	1.32	{±0.19} [±0.19]	23.3%
			After Catalyst	22.0	{±7.1} [±8.2]	20.2	{±5.4} [±7.1]	2.0	{±0.6} [±0.7]	1.01	{±0.18} [±0.18]	

Particulate Emission Rate Data
Table 8B

HOME CODE: W09

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
Energy King "King" (Conventional)	1	01/12/86-07/12/86	190.6	0.0	96.9%	N/A	100% FKLP	18.0	151.8	0.93	52.9%
	2	15/12/86-21/12/86	150.7	0.0	85.8%	N/A	100% FKLP	17.2	100.2	0.70	51.4%
	3	29/12/86-04/01/87	160.7	0.0	98.0%	N/A	100% SS	23.8	144.5	0.88	63.5%
	4	12/01/87-18/01/87	238.9	0.0	96.2%	N/A	100% SS	33.8	195.0	1.46	(g)
Osburn "Imperial 2000" (Low Emission Non-Catalytic)	5	09/02/87-15/02/87	197.1	0.0	97.4%	N/A	100% FKLP	15.9	165.0	1.01	37.6%(j)
	6	23/02/87-28/02/87	162.9	0.0	95.8%	N/A	100% FKLP	19.0	115.5	0.84	53.6%
	7	09/03/87-15/03/87	201.1	0.0	92.1%	N/A	100% FKLP	17.7	141.2	0.91	48.5%
	8	23/03/87-29/03/87	127.3	0.0	75.9%	N/A	100% SS	21.5	135.4	1.06	46.2%
	9	06/04/87-12/04/87	127.2	0.0	83.8%	N/A	100% SS	32.8	120.2	0.85	41.1%

Fueling, Burn Rate, and Efficiency Data

Table 9A

HOME CODE: W09

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3	
			Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Concentration	{P} [A][e]
Energy King "King" (Conventional)	1	01/12/86-07/12/86	18.2	{±4.5} [±5.8]	19.5	{±3.7} [±5.8]	1.9	{±0.4} [±0.6]	1.45	{±0.17} [±0.24]
	2	15/12/86-21/12/86	17.7	{±4.2} [±5.5]	25.4	{±4.6} [±7.3]	2.5	{±0.5} [±0.8]	2.06	{±0.24} [±0.34]
	3	29/12/86-04/01/87	11.3	{±2.5} [±3.2]	12.8	{±2.2} [±3.4]	1.0	{±0.2} [±0.3]	1.62	{±0.20} [±0.29]
Osburn "Imperial 2000" (Low Emission Non-Catalytic)	5[i]	09/02/87-15/02/87	19.4	{±6.2} [±8.0]	19.2	{±5.2} [±7.5]	2.6	{±0.7} [±1.1]	0.66	{±0.7} [±1.1]
	6	23/02/87-28/02/87	18.3	{±4.5} [±5.9]	21.8	{±4.2} [±6.5]	2.1	{±0.4} [±0.7]	1.92	{±0.26} [±0.36]
	7	09/03/87-15/03/87	17.1	{±4.3} [±5.4]	18.7	{±3.7} [±5.5]	1.9	{±0.4} [±0.6]	1.28	{±0.16} [±0.20]
	8	23/03/87-29/03/87	17.9	{±5.6} [±6.9]	16.8	{±4.3} [±6.1]	1.8	{±0.5} [±0.7]	0.80	{±0.13} [±0.14]
	9	06/04/87-12/04/87	22.2	{±6.7} [±8.8]	26.0	{±6.4} [±9.7]	3.1	{±0.8} [±1.2]	1.08	{±0.15} [±0.18]

Particulate Emission Rate Data
Table 9B

HOME CODE: W10

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
Fisher "Mama Bear" (Conventional)	1	01/12/86-07/12/86	190.6	0.2	99.2%	N/A	100% FKLP	18.3	212.9	1.28	52.5%
	2	15/12/86-21/12/86	150.7	7.6	59.4%	N/A	100% FKLP	16.0	114.3	1.15	56.2%
	3	29/12/86-04/01/87	160.7	1.1	54.6%	N/A	100% SS	17.5	132.4	1.44	54.3%
	4(f)	19/01/87-22/01/87	88.1	0.2	92.8%	N/A	100% SS	31.6	117.5	1.49	38.8%
with Security Vented Double-Wall Flue Pipe	5	09/02/87-15/02/87	197.1	0.4	98.3%	N/A	100% FKLP	16.5	223.6	1.36	49.7%
	6	23/02/87-28/02/87	162.9	0.3	97.8%	N/A	100% FKLP	16.7	153.1	1.09	50.2%
	7	09/03/87-15/03/87	201.1	0.7	98.0%	N/A	100% FKLP	18.7	181.5	1.10	38.6%
with James A. Ryder Air-Insulated Double-Wall Flue Pipe	8	23/03/87-29/03/87	127.3	1.0	58.4%	N/A	100% SS	21.7	181.5	1.85	48.7%
	9	06/04/87-12/04/87	127.2	0.1	53.9%	N/A	100% SS	37.8	128.6	1.42	41.1%

Fueling, Burn Rate, and Efficiency Data

Table 10A

HOME CODE: W10

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3	
			Emission Rate	{P} [A]^c	Emission Rate	{P} [A]^c	Emission Rate	{P} [A]^c	Concentration	{P} [A]^c
Fisher "Mama Bear" (Conventional)	1	01/12/86-07/12/86	28.6	{±6.2} [±7.8]	22.4	{±3.7} [±5.6]	2.2	{±0.4} [±0.6]	2.02	{±0.21} [±0.28]
	2	15/12/86-21/12/86	16.5	{±4.3} [±4.7]	14.4	{±3.0} [±3.8]	1.3	{±0.3} [±0.4]	1.01	{±0.13} [±0.13]
	3	29/12/86-04/01/87	22.5	{±5.8} [±6.4]	15.6	{±3.2} [±4.1]	1.4	{±0.3} [±0.4]	1.09	{±0.14} [±0.13]
	4$^{(f)}$	19/01/87-22/01/87	24.6	{±8.4} [±4.7]	16.5	{±4.7} [±6.9]	2.1	{±0.6} [±0.9]	0.57	{±0.09} [±0.09]
with Security Vented Double-Wall Flue Pipe	5	09/02/87-15/02/87	34.9	{±9.2} [±12.4]	25.8	{±5.4} [±8.6]	2.6	{±0.6} [±0.9]	1.31	{±0.15} [±0.19]
	6	23/02/87-28/02/87	26.4	{±7.8} [±10.0]	24.3	{±5.9} [±8.7]	2.4	{±0.6} [±0.9]	1.07	{±0.14} [±0.16]
	7	09/03/87-15/03/87	40.5	{±13.7} [±20.1]	36.7	{±10.5} [±17.4]	4.8	{±1.5} [±2.4]	0.97	{±0.11} [±0.14]
with James A. Ryder Air-Insulated Double-Wall Flue Pipe	8	23/03/87-29/03/87	27.1	{±10.1} [±11.4]	14.6	{±4.7} [±5.9]	1.5	{±0.5} [±0.6]	0.54	{±0.11} [±0.09]
	9	06/04/87-12/04/87	21.0	{±10.0} [±10.6]	14.8	{±5.8} [±6.8]	1.8	{±0.7} [±0.9]	0.48	{±0.12} [±0.09]

Particulate Emission Rate Data
Table 10B

HOME CODE: W11

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
RSF "65" (Conventional)	1	01/12/86-07/12/86	190.6	0.0	86.3%	N/A	100% FKLP	17.0	344.0	2.37	58.7%
	2	15/12/86-21/12/86	150.7	0.0	76.6%	N/A	100% FKLP	17.8	259.2	2.02	48.3%
	3	29/12/86-04/01/87	160.7	0.0	72.5%	N/A	100% SS	30.8	246.5	2.02	44.0%
	4	12/01/87-18/01/87	238.9	0.0	91.6%	N/A	100% SS	32.8	400.2	2.60	53.5%
Blaze King "King" (Integral Catalytic)	5	09/02/87-15/02/87	197.1	0.0	91.4%	85.0%	100% FKLP	15.3	278.8	1.84	63.4%
	6	23/02/87-28/02/87	162.9	0.0	89.1%	77.7%	100% FKLP	18.3	245.1	1.91	57.7%
	7	09/03/87-15/03/87	201.1	0.3	84.7%	69.5%	100% FKLP	17.8	233.8	1.64	56.6%
	8	23/03/87-29/03/87	127.3	0.0	72.7%	58.7%	95% SS 5% FKLP	46.1 16.4	180.1	1.48	52.8%
	9	06/04/87-12/04/87	127.2	0.0	51.2%	57.2%	100% SS	36.1	145.5	1.69	52.2%

Fueling, Burn Rate, and Efficiency Data

Table 11A

HOME CODE: W11

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Sampling Location	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3		Percent Emissions Reduction[h]
				Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Concen-tration	{P} [A][e]	
RSF "65" (Conventional)	1	01/12/86-07/12/86	Flue Collar	10.5	{±4.0} [±3.7]	4.4	{±1.4} [±1.5]	0.4	{±0.1} [±0.1]	0.29	{±0.07} [±0.05]	N/A
	2	15/12/86-21/12/86	Flue Collar	14.1	{±5.5} [±5.4]	7.0	{±2.4} [±2.5]	0.7	{±0.3} [±0.3]	0.30	{±0.07} [±0.04]	N/A
	3	29/12/86-04/01/87	Flue Collar	23.6	{±8.0} [±8.9]	11.7	{±3.3} [±4.1]	1.3	{±0.4} [±0.5]	0.51	{±0.09} [±0.08]	N/A
	4	12/01/87-18/01/87	Flue Collar	18.9	{±5.5} [±5.7]	7.2	{±1.7} [±2.0]	0.7	{±0.2} [±0.2]	0.48	{±0.08} [±0.07]	N/A
Blaze King "King" (Integral Catalytic)	5	09/02/87-15/02/87	Before Catalyst	57.1	{±12.7} [±16.1]	31.1	{±5.2} [±8.1]	3.1	{±0.6} [±0.9]	2.90	{±0.33} [±0.46]	77.1%
			After Catalyst	13.1	{±3.9} [±4.4]	7.1	{±1.7} [±2.2]	0.6	{±0.1} [±0.2]	0.43	{±0.07} [±0.07]	
	6	23/02/87-28/02/87	Before Catalyst	37.6	{±8.7} [±10.7]	19.6	{±3.5} [±5.2]	1.8	{±0.4} [±0.5]	1.57	{±0.18} [±0.23]	41.5%
			After Catalyst	22.0	{±6.5} [±7.2]	11.5	{±2.8} [±3.5]	1.0	{±0.3} [±0.3]	0.66	{±0.11} [±0.10]	
	7	09/03/87-15/03/87	Before Catalyst	43.8	{±9.8} [±12.3]	26.6	{±4.5} [±6.9]	2.8	{±0.5} [±0.8]	1.96	{±0.21} [±0.26]	74.2%
			After Catalyst	11.3	{±4.0} [±4.1]	6.9	{±2.1} [±2.3]	0.6	{±0.2} [±0.2]	0.37	{±0.08} [±0.07]	
	8	23/03/87-29/03/87	Before Catalyst(l)	32.6	{±11.2} [±14.1]	20.0	{±5.2} [±7.7]	2.0	{±0.6} [±0.8]	1.06	{±0.19} [±0.24]	63.2%
			After Catalyst	12.0	{±4.8} [±4.8]	8.1	{±2.6} [±2.9]	0.8	{±0.3} [±0.3]	0.35	{±0.08} [±0.06]	
	9	06/04/87-12/04/87	Before Catalyst	27.1	{±9.0} [±9.8]	16.0	{±3.9} [±5.0]	1.5	{±0.4} [±0.5]	0.88	{±0.14} [±0.14]	28.4%
			After Catalyst	19.4	{±7.3} [±7.3]	11.5	{±3.3} [±3.8]	1.1	{±0.3} [±0.4]	0.54	{±0.11} [±0.08]	

Particulate Emission Rate Data
Table 11B

HOME CODE: W12

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
Fisher "Papa Bear" (Conventional)	1	01/12/86-08/12/86	190.6	0.0	98.3%	N/A	100% FKLP	12.1	301.5	1.76	55.2%
	2	15/12/86-21/12/86	150.7	0.0	95.6%	N/A	100% FKLP	13.7	230.8	1.44	55.2%
	3	29/12/86-04/01/87	160.7	0.0	92.6%	N/A	100% FKLP	20.0	231.8	1.49	49.6%(j)
	4	12/01/87-18/01/87	238.9	0.0	96.7%	N/A	100% FKLP	18.1	295.0	1.82	52.9%
with Nu-Tec (Catalytic "Add-on" Retrofit)	5	09/02/87-15/02/87	197.1	0.0	97.5%	60.6%	100% FKLP	18.7	298.5	1.82	53.9%
	6	23/02/87-28/02/87	162.9	0.0	79.3%	51.3%	100% FKLP	15.3	203.5	1.78	57.5%
	7	09/03/87-15/03/87	201.1	0.0	95.7%	42.4%	100% FKLP	13.9	233.5	1.45	57.5%(j)
	8	23/03/87-29/03/87	127.3	0.0	58.3%	46.8%	95% SS 5% FKLP	43.2 13.5	137.0	1.40	52.0%
	9	06/04/87-12/04/87	127.2	0.0	62.6%	28.0%	100% FKLP	12.5	118.5	1.13	58.9%

Fueling, Burn Rate, and Efficiency Data

Table 12-A

HOME CODE: W12

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Sampling Location	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3		Percent Emissions Reduction[h]
				Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Concentration	{P} [A][e]	
Fisher "Papa Bear" (Conventional)	1	01/12/86-08/12/86	Flue Collar	26.7	{±6.2} [±7.7]	15.1	{±2.7} [±4.0]	1.4	{±0.3} [±0.4]	1.30	{±0.15} [±0.19]	N/A
	2	15/12/86-21/12/86	Flue Collar	20.3	{±5.0} [±6.1]	14.1	{±2.7} [±4.0]	1.3	{±0.3} [±0.4]	1.11	{±0.14} [±0.17]	N/A
	3(j)	29/12/86-04/01/87	Flue Collar	24.7	{±6.4} [±8.1]	16.6	{±3.4} [±5.0]	1.7	{±0.4} [±0.5]	1.04	{±0.13} [±0.16]	N/A
	4	12/01/87-18/01/87	Flue Collar	29.4	{±6.9} [±8.5]	16.2	{±2.9} [±4.3]	1.5	{±0.3} [±0.4]	1.30	{±0.15} [±0.19]	N/A
with Nu-Tec (Catalytic "Add-on" Retrofit)	5	09/02/87-15/02/87	Before Catalyst	36.0	{±9.0} [±11.7]	19.7	{±3.9} [±6.0]	2.1	{±0.5} [±0.7]	1.30	{±0.16} [±0.21]	38.1%
			After Catalyst	22.3	{±5.4} [±6.3]	12.2	{±2.3} [±3.2]	1.1	{±0.2} [±0.3]	0.90	{±0.11} [±0.12]	
	6	23/02/87-28/02/87	Before Catalyst	15.8	{±5.2} [±5.3]	8.8	{±2.4} [±2.8]	0.9	{±0.3} [±0.3]	0.55	{±0.11} [±0.09]	3.8%
			After Catalyst	15.2	{±4.1} [±4.4]	8.5	{±1.8} [±2.3]	0.7	{±0.2} [±0.2]	0.69	{±0.11} [±0.10]	
	7	09/03/87-15/03/87	Before Catalyst	34.7	{±7.9} [±10.2]	23.9	{±4.2} [±6.4]	2.6	{±0.5} [±0.8]	1.87	{±0.20} [±0.28]	53.9%
			After Catalyst(j)	16.0	{±3.8} [±4.6]	11.0	{±2.0} [±2.9]	1.0	{±0.2} [±0.3]	1.02	{±0.13} [±0.16]	
	8	23/03/87-29/03/87	Before Catalyst	28.2	{±8.6} [±9.9]	20.1	{±4.4} [±6.2]	2.1	{±0.5} [±0.7]	1.40	{±0.21} [±0.25]	36.9%
			After Catalyst	17.8	{±5.5} [±5.9]	12.7	{±2.9} [±3.6]	1.2	{±0.3} [±0.4]	0.91	{±0.14} [±0.14]	
	9	06/04/87-12/04/87	Before Catalyst	19.0	{±5.4} [±6.3]	16.9	{±3.9} [±5.2]	1.6	{±0.4} [±0.5]	1.06	{±0.16} [±0.17]	37.9%
			After Catalyst	11.8	{±3.3} [±3.7]	10.4	{±2.4} [±3.1]	0.9	{±0.2} [±0.3]	0.70	{±0.11} [±0.11]	

Particulate Emission Rate Data
Table 12B

HOME CODE: W13

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
Sears "Automatic" (Conventional)	2	15/12/86-21/12/86	150.7	0.3	97.5%	N/A	100% FKLP	20.6	258.7	1.85	45.6%
	3	29/12/86-04/01/87	160.7	0.0	99.8%	N/A	100% SLP	26.8	289.3	1.74	51.1%
Pacific Energy Systems (Low Emission Non-Catalytic)	5	09/02/87-15/02/87	197.1	0.1	100.0%	N/A	100% FKLP	16.1	216.7	1.29	47.6%
	6	23/02/87-28/02/87	162.9	0.4	99.4%	N/A	100% FKLP	15.7	192.6	1.35	53.4%
	7	09/03/87-15/03/87	201.1	4.3	100.0%	N/A	100% FKLP	19.1	199.5	1.19	48.2%
	8	23/03/87-29/03/87	127.3	0.7	97.6%	N/A	80% SLP 20% FKLP	19.6 18.1	146.4	0.89	49.8%
	9	06/04/87-12/04/87	127.2	0.0	93.1%	N/A	100% SLP	18.6	139.0	0.89	50.9%

Fueling, Burn Rate, and Efficiency Data

Table 13A

HOME CODE: W13

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3	
			Emission Rate	{P} [A]^e	Emission Rate	{P} [A]^e	Emission Rate	{P} [A]^e	Concen-tration	{P} [A]^e
Sears "Automatic" (Conventional)	2	15/12/86-21/12/86	33.0	{±10.2} [±12.5]	17.9	{±4.6} [±6.4]	2.0	{±0.5} [±0.7]	0.80	{±0.12} [±0.12]
	3	29/12/86-04/01/87	26.7	{±7.5} [±9.2]	15.4	{±3.5} [±5.0]	1.5	{±0.4} [±0.5]	0.92	{±0.13} [±0.16]
Pacific Energy Systems (Low Emission Non-Catalytic)	5	09/02/87-15/02/87	33.2	{±8.5} [±11.4]	25.7	{±5.2} [±8.2]	2.7	{±0.6} [±0.9]	1.62	{±0.20} [±0.28]
	6	23/02/87-28/02/87	16.4	{±4.7} [±5.6]	12.2	{±2.8} [±3.9]	1.2	{±0.3} [±0.4]	0.68	{±0.10} [±0.10]
	7	09/03/87-15/03/87	22.9	{±6.1} [±7.7]	19.3	{±4.1} [±6.1]	2.0	{±0.5} [±0.7]	1.18	{±0.15} [±0.19]
	8	23/03/87-29/03/87	17.5	{±4.9} [±6.5]	19.6	{±4.5} [±6.8]	2.0	{±0.5} [±0.7]	1.08	{±0.16} [±0.20]
	9	06/04/87-12/04/87	17.8	{±4.8} [±6.1]	20.0	{±4.3} [±6.4]	1.9	{±0.5} [±0.7]	0.98	{±0.12} [±0.14]

Particulate Emission Rate Data
Table 13B

HOME CODE: W14

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Heating Degree Days[a]	Alternative Heat Use (Hours)	Stove Operation (%)[b]	Catalyst Operation (%)[c]	Fuel Type[d]	Fuel Moisture (% db)	Fuel Use (dry kg)	Average Burn Rate (dry kg/hr)	Overall Efficiency
RSF "65" (Conventional)	1	01/12/86-07/12/86	190.6	2.3	98.0%	N/A	100% FKLP	17.7	190.1	1.16	44.7%
	2	15/12/86-21/12/86	150.7	1.0	96.8%	N/A	100% FKLP	19.0	174.7	1.07	39.9%
	3(f)	05/01/87-08/01/87	71.0	0.1	99.6%	N/A	100% SS	22.7	59.2	1.04	28.1%(j)
	4	12/01/87-18/01/87	238.9	1.0	100.0%	N/A	100% SS	26.3	286.7	1.71	37.2%
Burning Log "Turbo 10" (Integral Catalytic)	5	09/02/87-15/02/87	197.1	5.3	94.5%	78.8%	100% FKLP	17.3	188.5	1.19	54.5%
	6	23/02/87-28/03/87	162.9	6.5	61.1%	68.8%	100% FKLP	15.7	75.4	0.86	50.0%
	7	09/03/87-15/03/87	201.1	5.7	62.9%	76.2%	100% FKLP	15.6	115.7	1.09	56.1%
	8	23/03/87-29/03/87	127.3	1.4	92.1%	57.3%	100% SS	22.1	166.1	1.07	48.9%
	9	06/04/87-12/04/87	127.2	3.3	60.5%	59.6%	100% SS	33.6	87.0	0.86	50.8%

Fueling, Burn Rate, and Efficiency Data

Table 14A

HOME CODE: W14

Stove Model (Technology Type)	Sampling Period	Sampling Dates	Sampling Location	Grams per Hr		Grams per Kg		Grams per 10^6 J		Grams per m^3		Percent Emissions Reduction[h]
				Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Emission Rate	{P} [A][e]	Concen-tration	{P} [A][e]	
RSF "65" (Conventional)	1	01/12/86-08/12/86	Flue Collar	24.7	{±7.2} [±9.4]	21.4	{±5.1} [±7.7]	2.4	{±0.6} [±0.9]	1.01	{±0.14} [±0.16]	N/A
	2	15/12/86-21/12/86	Flue Collar	25.7	{±8.6} [±11.6]	23.9	{±6.7} [±10.2]	3.0	{±0.9} [±1.4]	0.83	{±0.12} [±0.14]	N/A
	3(f,j)	05/01/87-08/01/87	Flue Collar	32.6	{±13.4} [±18.8]	31.4	{±11.3} [±17.4]	5.5	{±2.1} [±3.2]	0.68	{±0.10} [±0.10]	N/A
	4	12/01/87-18/01/87	Flue Collar	28.0	{±9.7} [±12.3]	16.4	{±4.7} [±6.8]	2.2	{±0.7} [±1.0]	0.61	{±0.10} [±0.11]	N/A
Burning Log "Turbo 10" (Integral Catalytic)	5	09/02/87-15/02/87	Before Catalyst	30.2	{±6.7} [±8.6]	25.4	{±4.3} [±6.7]	2.8	{±0.5} [±0.8]	2.13	{±0.23} [±0.32]	79.5%
			After Catalyst	6.2	{±2.1} [±2.2]	5.2	{±1.5} [±1.7]	0.5	{±0.1} [±0.2]	0.33	{±0.07} [±0.06]	
	6	23/02/87-28/02/87	Before Catalyst	22.2	{±5.7} [±7.2]	25.9	{±5.3} [±7.8]	2.9	{±0.7} [±1.0]	1.77	{±0.24} [±0.30]	55.0%
			After Catalyst	10.0	{±3.3} [±3.7]	11.7	{±3.2} [±4.0]	1.2	{±0.3} [±0.4]	0.68	{±0.13} [±0.13]	
	7	09/03/87-15/03/87	Before Catalyst	9.4	{±3.0} [±3.2]	8.6	{±2.3} [±2.8]	0.8	{±0.2} [±0.3]	0.64	{±0.13} [±0.13]	54.3%
			After Catalyst	4.3	{±1.8} [±1.4]	3.9	{±1.5} [±1.2]	0.3	{±0.1} [±0.1]	0.24	{±0.07} [±0.04]	
	8	23/03/87-29/03/87	Before Catalyst	47.8	{±11.3} [±15.2]	44.5	{±8.2} [±13.2]	6.5	{±1.3} [±2.1]	2.48	{±0.26} [±0.36]	67.8%
			After Catalyst	15.4	{±4.0} [±4.7]	14.3	{±2.9} [±4.1]	1.5	{±0.3} [±0.4]	0.79	{±0.10} [±0.10]	
	9	06/04/87-12/04/87	Before Catalyst	25.9	{±7.0} [±8.9]	30.3	{±6.6} [±9.7]	4.1	{±1.0} [±1.4]	1.45	{±0.18} [±0.21]	68.3%
			After Catalyst	8.2	{±2.6} [±2.6]	9.6	{±2.6} [±2.8]	0.9	{±0.3} [±0.3]	0.54	{±0.10} [±0.08]	

Particulate Emission Rate Data
Table 14B

Footnotes For Tables 1–A Through 14–B

a. Heating degree days as recorded at Whitehorse Airport; total heating degree days for sampling period.

b. Percentage of total possible operating hours during sampling period stove is operational; based on stack temperature greater than 38°C (100°F).

c. Percentage of stove operation time catalyst active, based on in-catalyst temperature greater than 260°C (500°F).

d. "FKLP" = Firekilled Lodgepole Pine; "SLP" = Seasoned Lodgepole Pine; "SS" = Seasoned Spruce.

e. Estimated precision and accuracy based on total propagation of uncertainties of individual measurements used in the emissions calculations.

f. Sampling period less than seven days.

g. Data not available due to equipment malfunction.

h. Percent emission reduction based on grams per hour data; i.e. 1 – [(after-catalyst g/hr) divided by (before-catalyst g/hr)]. (Note: Most catalytic stoves are designed to "feed" an enriched fuel combustion mixture to the catalyst. Therefore, interpretation of catalyst performance based on this data may be misleading.)

i. These values are the upper limit of estimated particulate emission rates due to estimation of particulate content in partial loss of AWES hardware methanol solvent rinse.

j. Ambient oxygen (O_2) value greater than 20.9% ± 2.0% absolute at final calibration. Therefore, calculated emissions (g/hr, g/kg, g/10^6J) and overall efficiency therefore have a potentially higher degree of associated uncertainty than noted by the precision and accuracy values. Concentration (g/m^3) uncertainty is unaffected since O_2 values are not used in this calculation.

k. Equipment malfunction during sampling period; actual sampling days 3/30, 3/31, 4/1, and 4/5.

l. Before-catalyst sampler started one day late; actual sampling dates 3/24–3/29.

Table 15 summarizes the mean particulate emission rates in grams per hour for each stage in each home. The student "t" statistical test was applied to the emission rate data to determine if there was a statistically significant difference in the mean emission rates between Stage 1 and Stage 2. A low probability indicates that the two mean emission rates are statistically different, and a high probability indicates that the two mean emission rates are statistically alike.

Table 16 summarizes the mean burn rate data by home for each stage, and Table 17 summarizes the mean overall efficiency data of the individual woodheat technologies used in each home during each stage. As in the case of the Table 15 data, the student "t" statistical test was applied to the means of the data.

Table 18 lists wood use in kilograms (dry) per heating degree-day (HDD). The heating degree-days used in these calculations have been adjusted to reflect actual stove operation hours.

Table 19 summarizes the creosote accumulation data collected during the study. For purposes of comparing the creosote accumulation data the weight of creosote was normalized by using heating degree-day data. Due to the inherent difficulties associated with the collection and quantification of creosote mass, this data has a high level of uncertainty associated with it. Therefore, caution needs to be exercised in the interpretation of the creosote deposition rate data.

Table 20 lists the mean catalyst lightoff time percentage and the mean emission rate for those homes that used catalytic technology in Stage 2. Catalyst lightoff figures reflect the percentage of time that the catalyst was at lightoff conditions while the stove was in operation. Catalyst lightoff conditions were defined as when the catalyst temperature is greater than 260°C (500°F). (Note: The decision to use in-catalyst temperature greater the 260°C [500°F] as an indicator of catalyst light-off performance was based on a correlation analysis of two catalyst light-off assessment methodologies versus after-catalyst emission rates [grams per hour]. This analysis indicated that using an in-catalyst threshold temperature of 260°C [500°F] to indicate catalyst light-off performance appeared to better correlate with after-catalyst emission data than the method based on a positive difference between in-catalyst and inlet temperatures [ΔT method]. However, in several individual cases [i.e., per home basis], both methods did not correlate [i.e., $r > -0.7$] with after-catalyst emissions. It would appear that catalyst light-off is not a reliable indicator of stove emission performance when there is a failure[s] in the emission control system of catalytic stoves.) The table also lists overall mean catalyst lightoff time percentages for each Stage 2 catalytic technology by model and by technology classification.

TABLE 15

MEAN GRAMS PER HOUR PARTICULATE EMISSION RATES

Home Code	Stage	Technology	g/hr	σ[a]	N[b]	Probability[c]
W01	1	RSF "65"	35.3	12.7	3	10-20%
	2[d]	Double Wall Flue Pipe	25.7	5.9	5	
W02	1	RSF "65"	17.6	6.1	6	< 10%
	2[e]	w/ Nu-Tec	36.6	0.0	1	
W03	1	Fisher "Grandma Bear"	9.4	3.2	4	> 90%
	2	Burning Log "Turbo 10"	9.2	2.1	5	
W04	1	Sears "Automatic"	33.0	6.5	4	< 10%
	2	Osburn "Imperial 2000"	9.6	2.7	5	
W05	1	Acorn "Ranger"	14.3	5.0	4	20-30%
	2	w/ Uni-Com	10.2	4.3	3	
W06	1	Energy King "Princess"	17.9	1.9	3	40-50%
	2	PES "Super 27" (uncertified)	15.7	4.5	5	
W07	1	Blaze King "King" (Conv.)	29.8	7.2	3	< 10%
	2	Blaze King "King" (Cat.)	15.3	9.3	4	
W08	1	RSF "65"	28.5	5.2	3	< 10%
	2	w/ Uni-Com	15.0	5.1	4	
W09	1	Energy King "King" (Conv.)	15.7	3.8	3	10-20%
	2	Osburn "Imperial 2000"	19.0	2.0	5	
W10	1	Fisher "Mama Bear"	23.1	5.0	4	80-90%
	2[d]	Double Wall Flue Pipe	30.0	5.0	5	
W11	1	RSF "65"	16.8	5.7	4	70-80%
	2	Blaze King "King" (Cat.)	15.6	4.8	5	
W12	1	Fisher "Papa Bear"	25.3	3.8	4	< 10%
	2	w/ Nu-Tec	16.6	5.0	5	
W13	1	Sears "Automatic"	29.9	4.5	2	10-20%
	2	PES "Super 27" (uncertified)	21.6	7.0	5	
W14	1	RSF "65"	27.8	3.5	4	< 10%
	2	Burning Log "Turbo 10"	8.8	4.3	5	

a. Standard deviation.
b. Number of data values used to calculate mean g/hr emission rate.
c. Probability of mean emission rates for Stages 1 and 2 being statistically alike.
d. Double wall flue pipe emission rate is an overall mean of both Security and James A. Ryder flue pipe data set.
e. Stage 2 data values include only sampling periods with Nu-Tec installed.

TABLE 16

MEAN BURN RATES

Home Code	Stage	Technology	Mean Burn Rate (Dry kg/hr)	σ[a]	N[b]	Probability[c]
W01	1	RSF "65"	1.50	0.37	3	80–90%
	2[d]	Double Wall Flue Pipe	1.43	0.51	5	
W02	1	RSF "65"	1.07	0.38	6	> 90%
	2[e]	w/ Nu-Tec	1.04	0.25	2	
W03	1	Fisher "Grandma Bear"	1.24	0.17	4	10–20%
	2	Burning Log "Turbo 10"	1.06	0.15	5	
W04	1	Sears "Automatic"	1.76	0.34	4	< 10%
	2	Osburn "Imperial 2000"	1.24	0.17	5	
W05	1	Acorn "Ranger"	1.66	0.06	4	10–20%
	2	w/ Uni-Com	1.45	0.28	5	
W06	1	Energy King "Princess"	1.19	0.11	4	< 10%
	2	PES "Super 27" (uncertified)	0.86	0.25	5	
W07	1	Blaze King "King" (Conv.)	2.21	0.29	4	< 10%
	2	Blaze King "King" (Cat.)	1.67	0.16	4	
W08	1	RSF "65"	1.59	0.25	4	20–30%
	2	w/ Uni-Com	1.38	0.29	5	
W09	1	Energy King "King" (Conv.)	0.99	0.33	4	70–80%
	2	Osburn "Imperial 2000"	0.93	0.10	5	
W10	1	Fisher "Mama Bear"	1.34	0.16	4	> 90%
	2[d]	Double Wall Flue Pipe	1.36	0.31	5	
W11	1	RSF "65"	2.25	0.28	4	< 10%
	2	Blaze King "King" (Cat.)	1.71	0.17	5	
W12	1	Fisher "Papa Bear"	1.63	0.19	4	50–60%
	2	w/ Nu-Tec	1.52	0.29	5	
W13	1	Sears "Automatic"	1.80	0.08	2	< 10%
	2	PES "Super 27" (uncertified)	1.12	0.22	5	
W14	1	RSF "65"	1.25	0.31	4	10–20%
	2	Burning Log "Turbo 10"	1.01	0.15	5	

a. Standard Deviation

b. Number of data values used to calculate mean burn rates

c. Probability of mean burn rates for stages 1 and 2 being statistically alike.

d. Double wall flue pipe burn rate is an overall mean of both Security and James A. Ryder flue pipe data set.

e. Stage 2 data values include only sampling periods with Nu-Tec installed.

TABLE 17

MEAN OVERALL EFFICIENCY

Home Code	Stage	Technology	Mean Overall Efficiency[a]	σ[b]	N[c]	Probability[d]
W01	1	RSF "65"	44.0%	2.4	3	> 90%
	2[e]	Double Wall Flue Pipe	48.4%	4.4	5	
W02	1	RSF "65"	51.6%	6.2	6	20–30%
	2[f]	w/ Nu-Tec	42.9%	0	1	
W03	1	Fisher "Grandma Bear"	56.4%	4.9	4	70–80%
	2	Burning Log "Turbo 10"	55.5%	3.7	5	
W04	1	Sears "Automatic"	42.1%	2.1	4	< 10%
	2	Osburn "Imperial 2000"	50.9%	3.6	5	
W05	1	Acorn "Ranger"	49.7%	7.0	4	< 10%
	2	w/ Uni-Com	60.8%	3.0	3	
W06	1	Energy King "Princess"	55.9%	3.5	3	60–70%
	2	PES "Super 27" (uncertified)	54.4%	5.0	5	
W07	1	Blaze King "King" (Conv.)	50.4%	7.2	3	10–20%
	2	Blaze King "King" (Cat.)	60.6%	8.2	4	
W08	1	RSF "65"	44.0%	7.0	3	< 10%
	2	w/ Uni-Com	53.5%	3.5	4	
W09	1	Energy King "King" (Conv.)	55.9%	6.6	3	< 10%
	2	Osburn "Imperial 2000"	45.4%	6.3	5	
W10	1	Fisher "Mama Bear"	50.5%	7.9	4	30–40%
	2[e]	Double Wall Flue Pipe	45.7%	4.8	5	
W11	1	RSF "65"	51.1%	6.4	4	10–20%
	2	Blaze King "King"	56.5%	4.5	5	
W12	1	Fisher "Papa Bear"	52.5%	2.3	4	10–20%
	2	w/ Nu-Tec	56.0%	2.9	5	
W13	1	Sears "Automatic"	48.4%	3.9	2	50–60%
	2	PES "Super 27" (uncertified)	50.0%	2.3	5	
W14	1	RSF "65"	37.5%	7.0	4	< 10%
	2	Burning Log "Turbo 10"	52.1%	3.1	5	

a. Mean overall efficiency calculated using a modified version of the Condar method.
b. Standard deviation.
c. Number of data values used to calculate mean efficiency.
d. Probability of mean overall efficiencies for stages 1 and 2 being statistically alike.
e. Double wall flue pipe overall efficiency is an overall mean of both Security and James A. Ryder flue pipe data set.
f. Stage 2 data values include only sampling periods with Nu-Tec installed.

TABLE 18

WOOD USE ANALYSIS

Home Code	Technology	Stage	Dry kg Wood Use/HDD[a]	Net Change in Wood Use (%)
W01	RSF "65"	1	2.21	−37.1
	Double Wall Flue Pipe	2	1.39	
W02	RSF "65"	1	1.09	+4.5
	w/ Nu-Tec	2	1.14	
W03	Fisher "Grandma Bear"	1	1.28	−23.4
	Burning Log "Turbo 10"	2	0.98	
W04	Sears "Automatic"	1	1.82	−36.8
	Osburn "Imperial 2000"	2	1.15	
W05	Acorn "Ranger"	1	1.71	−25.3
	w/ Uni-Com	2	1.27	
W06	Energy King "Princess"	1	1.25	−39.8
	PES "Super 27" (uncertified)	2	0.75	
W07	Blaze King "King" (Conv.)	1	2.26	−17.5
	Blaze King "King" (Cat.)	2	1.86	
W08	RSF "65"	1	1.42	−9.6
	w/ Uni-Com	2	1.28	
W09	Energy King "King" (Conv.)	1	0.84	+9.0
	Osburn "Imperial 2000"	2	0.91	
W10	Fisher "Mama Bear"	1	1.30	−3.0
	Double Wall Flue Pipe	2	1.26	
W11	RSF "65"	1	2.04	−5.9
	Blaze King "King"	2	1.91	
W12	Fisher "Papa Bear"	1	1.50	0.0
	w/ Nu-Tec	2	1.50	
W13	Sears "Automatic"	1	1.92	−42.0
	PES "Super 27" (uncertified)	2	1.11	
W14	RSF "65"	1	1.19	−12.8
	Burning Log "Turbo 10"	2	1.03	

a. kg (dry) of wood use per Heating Degree-Day (HDD). Heating Degree-Days adjusted to actual stove operation time.

TABLE 19

CREOSOTE ANALYSIS

Home Code	Technology	Stage	Grams/HDD[a]
W01	RSF "65"	1	1.48
	Double Wall Flue Pipe	2	1.48
W02	RSF "65"	1	0.59
	w/ Nu-Tec	2	0.71
W03	Fisher "Grandma Bear"	1	0.91
	Burning Log "Turbo 10"	2	0.67
W04	Sears "Automatic"	1	0.58
	Osburn "Imperial 2000"	2	0.37
W05	Acorn "Ranger"	1	0.40
	w/ Uni-Com	2	0.56
W06	Energy King "Princess"	1	1.60
	PES "Super 27" (uncertified)	2	2.17
W07	Blaze King "King" (Conv.)	1	1.48
	Blaze King "King" (Cat.)	2	1.11
W08	RSF "65"	1	0.85
	w/ Uni-Com	2	0.92
W09	Energy King "King" (Conv.)	1	1.28
	Osburn "Imperial 2000"	2	0.49
W10	Fisher "Mama Bear"	1	2.98
	Double Wall Flue Pipe	2	0.87
W11	RSF "65"	1	0.51
	Blaze King "King"	2	0.52
W12	Fisher "Papa Bear"	1	0.81
	w/ Nu-Tec	2	1.04
W13	Sears "Automatic"	1	0.26
	PES "Super 27" (uncertified)	2	1.22
W14	RSF "65"	1	1.56
	Burning Log "Turbo 10"	2	0.65

a. Grams creosote collected per heating degree-day; measured during creosote deposition period.

TABLE 20

MEAN CATALYST LIGHTOFF TIME PERCENTAGES

Catalytic "Add-On" Retrofit Devices:

Home Code	Technology	Mean Catalyst Lightoff Percentage[a]	Mean Emission Rate (g/hr)[b]
W02	RSF "65"/Nu-Tec	9.4%	36.6
W05	Acorn "Ranger"/Uni-Com	49.8%	10.2
W08	RSF "65"/Uni-Com	40.3%	15.0
W12	Fisher "Papa Bear"/Nu-Tec	45.8%	16.6

Integral Catalytic Woodstoves:

Home Code	Technology	Mean Catalyst Lightoff Percentage[a]	Mean Emission Rate (g/hr)[b]
W03	Burning Log "Turbo 10"	69.5%	9.2
W07	Blaze King "King"	77.3%	15.3
W11	Blaze King "King"	69.6%	15.6
W14	Burning Log "Turbo 10"	68.1%	8.8

Technology	Mean Lightoff Percentages[a]	Mean Emission Rate (g/hr)[b]	Percent Emission Reduction[c]
All Catalytic "Add-On" Retrofit Devices	41.1%	16.2	37.8
All Integral Catalytic Woodstoves	70.8%	12.1	55.9

a. Catalyst lightoff time percentage is the percentage of total stove operation time that the catalyst temperature is greater than 260°C (500°F).

b. Particulate emission rate data presented without precision and accuracy figures.

c. Percent emission reduction based on grams per hour data, i.e. [(after-catalyst g/hr) divided by (before-catalyst g/hr)] × 100.

B. Discussion of Data

Home W01

Stage 1: RSF "65"

Stage 2: Double Wall Flue Pipe

The overall mean particulate emission rate in home W01 was reduced from 35.3 g/hr to 25.7 g/hr after installation of the double wall flue pipe. The particulate emission rate observed in sampling period 1 was the highest observed in the home at 49.8 g/hr, a figure which significantly affects the mean Stage 1 emission rate. The mean emission rate for Stage 1 with sampling period 1 removed is 28.1 g/hr, therefore the removal of sampling period 1 from the Stage 1 data results in the Stage 1 and Stage 2 mean emission rates being statistically the same. A high burn rate (1.93 kg/hr) was observed in sampling period 1, which may have contributed to a higher emission rate.

The Security double wall flue pipe system with the ventilated airspace had a mean emission rate of 31.0 g/hr, while the James A. Ryder double wall flue pipe system with the sealed airspace had a mean emission rate of 22.1 g/hr. The double wall flue pipe with the vented airspace generates convection along the pipe surfaces in the airspace. The convection promotes heat transfer from the flue to the room, allowing closer flue-pipe-to-wall clearances.

Within three days after the installation of the vented Security double wall flue pipe, it was observed that creosote almost completely clogged the pipe resulting in a severe smoke spillage problem. This problem was not observed during Stage 1. The vented pipe was frequently swept until it was replaced with the sealed double wall Ryder flue pipe on the 25th of February. After the installation of the sealed double wall flue pipe, it was observed that only a very light coating of creosote formed inside the flue pipe portion of the chimney system. It was therefore hypothesized that the vented double wall pipe caused a thermosiphon effect resulting in a rapid cooling of flue gases and a concentration of creosote in the vented flue pipe. Additional analysis which is beyond the scope of this project would be needed to confirm if the observed rapid creosote buildup associated with vented double wall flue pipe would be generally applicable to stove installations and meteorological conditions found in the Whitehorse area.

The double wall pipe did not appear to significantly affect the observed burn rate in this home. The Stage 1 mean burn rate was 1.50 kg/hr, and the Stage 2 mean burn rate was 1.43 kg/hr. The homeowner noted that the woodstove's draft was improved with the Security system; however, no change was noted in the heat output of the woodstove.

The double wall pipe slightly increased the overall efficiency of the woodstove from 44.0% to 48.4%. The decrease in overall efficiencies during sampling periods 8 and 9 is probably due to the increase in the number of cold-to-cold burn cycles. While a statistical comparison indicates that the increased efficiency is not statistically significant, the data in Table 18 indicates a 37.1% decrease in wood use (dry kg) per heating degree-day in Stage 2. This observed decrease in wood usage also parallels the observed decrease in burn rates in Stage 2.

The creosote accumulation rate measured with the double wall pipe in place was identical to that with the single wall in place (1.48 g/HDD in both Stage 1 and Stage 2). The homeowner observed more creosote deposition after installation of the Security double wall pipe; however, the perceived change may have been a result of a relocation of creosote deposition areas due to the change in heat transfer characteristics of the chimney system.

Alternate heat use appeared to slightly increase during the coldest measured sampling period (#7) and towards the end of the heating season (sampling periods 8 and 9) when woodstove operation time decreased.

Home W02

Stage 1: RSF "65"

Stage 2: Nu-Tec Catalytic Retrofit

An incomplete data set was obtained for the Stage 2 technology in home W02. Immediately after the initial installation of the Nu-Tec Catalytic Retrofit, home W02 reported excessive smoke spillage from the stove door and from the catalytic retrofit housing when fueling the stove. Smoke spillage from the unit housing was reduced after two days as the machine oil burned off the housing of the Nu-Tec; however, the smoke spillage from the stove door during fueling events continued. The smoke spillage was caused by the catalytic retrofit device acting as a flue restriction. The mean particulate gram per hour emissions were 17.6 (Stage 1) and 36.6 g/hr (Stage 2). The increased emission rate on Stage 2 is due to decreased combustion efficiency coupled with the catalyst by-pass being kept in the open position during most of the sampling period. Wood use also slightly increased during the period that the retrofit device was installed.

The Nu-Tec was monitored during sampling periods 5 and 6; however, particulate emission data was only obtained during sampling period 5 due to an equipment malfunction during sampling period 6. The particulate emission rate measured during sampling period 5 was 36.6 g/hr, which was significantly higher than particulate emission rates observed with the same catalytic retrofit model in home W12.

The catalyst lightoff time percentages for sampling periods 5 and 6 were 12.2% and 6.7%, respectively, with a mean catalyst lightoff time percentage of 9.4%. These values were the lowest mean catalyst lightoff time percentages observed in the study. An analysis of catalyst and flue gas temperatures revealed that the bypass mechanism was kept in the "open" position (i.e., catalyst not engaged) the majority of time during sampling period 5. This observation was a result of the study participants trying to minimize smoke spillage during fuel loading events. While the catalyst was engaged the majority of time during sampling period 6, there was no noticeable improvement in catalyst light-off time.

Attempts to bring in additional outside combustion air via an open basement window near the stove and an outside air duct connected to the stove were not effective in reducing the observed smoke spillage problems. It appeared that none of the attempted mitigation measures were effective in reducing the flue restriction problems caused by the "add-on" device.

At the request of the study participants the catalytic retrofit device was removed at the end of sampling period 6.

Sampling continued in the home after the removal of the catalytic retrofit. The data from sampling periods 7, 8, and 9 provided additional baseline data on the RSF "65" conventional technology woodstove. Alternative heat use was the greatest (37 hours) during sampling period #1, which had the highest measured heating degree-days.

Home W03

Stage 1: Fisher "Grandma Bear"

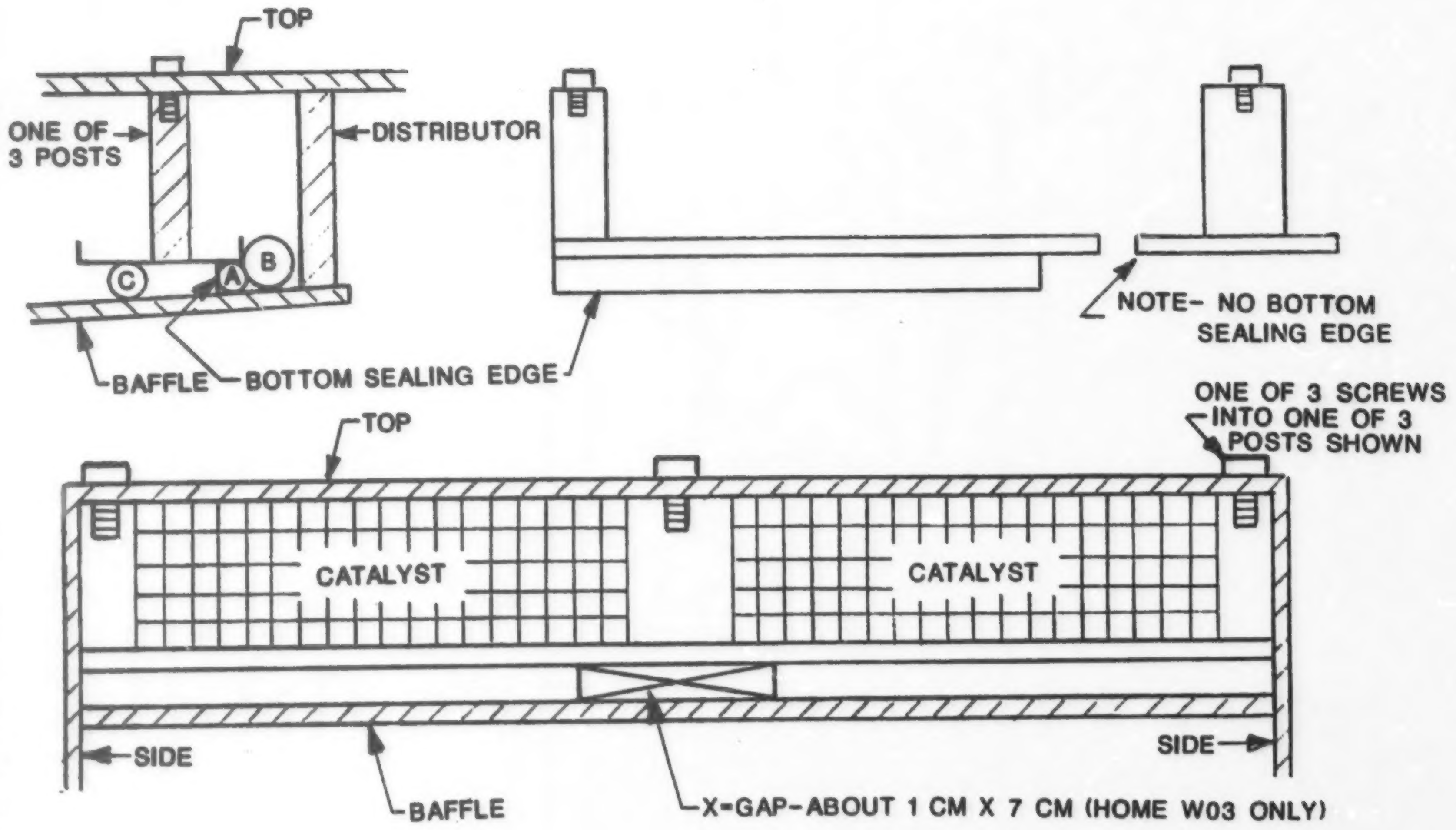
Stage 2: Burning Log "Turbo 10"

The mean particulate gram per hour emission rates observed in home W03 were similar for Stage 1 and Stage 2—9.4 g/hr and 9.2 g/hr, respectively. The Stage 1 conventional technology woodstove had a mean particulate emission rate that is considered very low for a conventional technology woodstove.

The mean Stage 2 burn rate of 1.06 kg/hr was significantly lower than the mean Stage 1 burn rate of 1.24 kg/hr. This observation is probably a result of the differences in firebox size between the Fisher "Grandma Bear" (0.0997 m^3 [3.52 ft^3]) and the Burning Log "Turbo 10" (0.0651 m^3 [2.3 ft^3]). Wood use also decreased 23.4% from 1.28 dry kg/HDD (Stage 1) to 0.98 dry kg/HDD (Stage 2). However, as in the case with burn rates, the observed difference in wood use is also being influenced by differences in firebox size.

An inspection of the catalysts and the fiberglass-like gasket below the catalyst was conducted by representatives of Energy, Mines and Resources Canada and Griffith's Heating on September 24, 1987. Both catalysts (Corning Model 6000—serial numbers 904809 and 9048231) appeared to be in good condition. It was observed, however, that catalyst gasketing material had shrunk to approximately 0.5 cm (0.19 in) below the center support bracket, creating a 1.0 cm × 7.0 cm (0.39 in × 2.75 in) gap (refer to Figure 3). The gasket material melted to a glass-like substance. Assuming the observed gasket gap occurred during the Stage 2 sampling period, it did not appear to have any noticeable effect on the emission performance of the stove since homes W03 and W14 had mean emission rates of 9.2 g/hr and 8.8 g/hr, respectively. The differences in mean emission rates between the two homes is considered statistically insignificant given the associated accuracy of the sampling method.

The catalyst lightoff time percentages ranged from 53.1% to 82.6%, with a mean lightoff percentage of 69.5%. The 53.1% figure was recorded during sampling period 9 and was probably lower


TOP
ONE OF 3 POSTS
DISTRIBUTOR
B
A
C
BAFFLE
BOTTOM SEALING EDGE
NOTE- NO BOTTOM SEALING EDGE
ONE OF 3 SCREWS INTO ONE OF 3 POSTS SHOWN
TOP
CATALYST
CATALYST
SIDE
SIDE
BAFFLE
X=GAP-ABOUT 1 CM X 7 CM (HOME W03 ONLY)

HOME W03-GASKET B ONLY

HOME W14-GASKET A & C ONLY

CATALYTIC COMBUSTOR
SCHEMATIC-TURBO 10
FIGURE 3

than other sampling periods due to warmer weather at this time. The lowest burn rate as averaged over the AWES sampling period of 0.86 kg/hr was also observed during sampling period 9.

The overall efficiency was slightly reduced from 56.4% to 55.5% in Stage 2; however, statistical analysis suggests that the difference is probably insignificant. The creosote deposition rate decreased from 0.91 g/HDD (Stage 1) to 0.67 g/HDD (Stage 2). There was no measured use of alternative heat during the sampling periods.

Home W04

Stage 1: Sears "Automatic"

Stage 2: Osburn "Imperial 2000"

Home W04 exhibited one of the largest relative particulate emission rate reductions after installation of the Stage 2 technology observed in this study. Stage 2 particulate emission rates ranged from 5.3 g/hr to 12.8 g/hr.

In addition to the lower particulate emission rates, the mean burn rate was significantly reduced from 1.76 kg/hr (Stage 1) to 1.24 kg/hr (Stage 2). Observed creosote deposition rates were reduced from 0.58 g/HDD (Stage 1) to 0.37 g/HDD (Stage 2). The mean overall efficiency in Stage 2 (50.9%) was significantly higher than in Stage 1 (42.1%).

While the homeowner indicated that burn the time between refuelings was not long enough to satisfy heating demand needs during the coldest periods, the new technology woodstove was an improvement over the conventional technology stove in that they used less wood per refueling. This observation is supported by an observed 36.8% decrease in wood usage per heating degree-day in Stage 2.

The only substantial use of alternative heat use (23.9 hours) was during sampling period 7 which had the highest number of heating degree-days. This observation would support the study participant's comment that the "Imperial 2000" stove could not meet heating demand needs during the coldest measured period.

Home W05

Stage 1: Acorn "Ranger"

Stage 2: Uni-Com Catalytic Damper

The mean particulate emission rates were reduced from 14.3 g/hr (Stage 1) to 10.2 g/hr (Stage 2) in home W05. The mean gram per hour emission rate from the Stage 1 conventional technology woodstove was at the low end of the range for conventional technology woodstoves. The low conventional technology emission rate reflects good combustion conditions due to the relatively high burn rate (1.66 kg/hr) maintained during Stage 1.

The mean burn rate also was reduced from 1.66 kg/hr (Stage 1) to 1.45 kg/hr (Stage 2). Creosote deposition was higher in Stage 2 (0.40 g/HDD in Stage 1, 0.56 g/HDD in Stage 2), although the uncertainty associated with the creosote collection method indicates that this difference may be inaccurate. Calculated overall efficiency did significantly improve from 49.7% (Stage 1) to 60.8% (Stage 2). Wood usage decreased 25.3% per heating degree-day during Stage 2.

Catalyst lightoff time percentages ranged from 35.7% to 69.5% with a mean lightoff percentage of 49.8%. This homeowner achieved one of the highest percentages of catalyst lightoff time in the catalytic retrofit technology classification and also had the lowest mean emission rate for catalytic retrofits observed in the study.

After installation of the Uni-Com Catalytic Damper the homeowner experienced smoke spillage problems when fueling the stove and did not feel that the catalytic retrofit improved the performance of the stove. Several mitigation measures were tried to reduce or eliminate the smoke spillage problem. Longer smoke flaps were added to the Acorn "Ranger." Basement windows were opened during fueling events to improve draft conditions. Prior to opening the door of the stove, the burn rate was increased to improve draft conditions. While these measures partially mitigated the smoke spillage problem, they did not completely eliminate the problem. Relative to home W02, the observed smoke spillage problems in home W05 were not as severe. The Uni-Com was removed at the conclusion of the study at the request of the study participant.

Home W06

Stage 1: Energy King "Princess"

Stage 2: Pacific Energy Systems "Super 27" (uncertified version)

Mean particulate emission rates were reduced from 17.9 g/hr (Stage 1) to 15.7 g/hr (Stage 2). Statistical analysis indicates that there is a 40% to 50% chance that the rates are different. The mean burn rate was significantly reduced from 1.19 kg/hr (Stage 1) to 0.86 kg/hr (Stage 2), but this may be an artifact of differences in the firebox size rather than improved overall efficiency. Wood use decreased from 1.25 kg (dry)/HDD (Stage 1) to 0.75 kg (dry)/HDD (Stage 2)—a decrease of 39.5%. However, this observed decreased in wood usage is believed to be primarily influenced by differences in firebox size.

Overall efficiency was slightly reduced from 55.9% in Stage 1 to 54.4% in Stage 2; however, statistical analysis indicates that the reduction is not statistically significant. Observed creosote deposition significantly increased from 1.67 g/HDD (Stage 1) to 2.17 g/HDD (Stage 2). A substantial increase in the creosote deposition rate was also observed in home W13 which also had the "Super 27" installed. As previously noted, caution should be used in the interpretation of this creosote deposition rate data. The "Super 27" was removed from home W06 at the end of study because of the homeowner's dissatisfaction with the heat output and frequent refuelings required.

The only noticeable increase in alternative heat usage occurred during the coldest observed sampling period (7). However, even during this time period total usage represented only less than seven hours during a week. Therefore it appears, despite homeowner complaints about frequent refuelings, the stove did satisfy most of the heat demand requirements during the study period.

An inspection of the Pacific Energy Systems (PES) "Super 27" stove used in home W06 was conducted on August 5, 1987. It was discovered that the stove used was an uncertified (i.e., not Oregon certified) version of the "Super 27." The stove did not contain the secondary air combustion system as required in the certified version. There was no Oregon certification label on the stove, but the safety listing label indicated that an Oregon certified version was available from Pacific Energy Systems. The stove dealer that supplied the PES stoves to the study was under the impression that the "Super 27" stoves used in the study were Oregon certified.

Since the "Super 27" used in home W06 was uncertified, the data is being treated as conventional technology stove performance information.

Home W07

Stage 1: Blaze King "King" (non-catalytic)

Stage 2: Blaze King "King" (integral catalytic)

Mean particulate emission rates were significantly reduced from 29.8 g/hr (Stage 1) to 15.3 g/hr (Stage 2). The emission rates in the first two sampling periods of Stage 2 were significantly lower than the emission rates in the final two sampling periods of Stage 2. This is probably indicative of a progressive problem with the woodstove's emission control system as discussed in more detail below.

Mean burn rate was significantly reduced from 2.21 kg/hr (Stage 1) to 1.67 kg/hr (Stage 2), and mean overall efficiency was significantly improved from 50.4% to 60.6%. Wood usage decreased from 2.26 kg/HDD (Stage 1) to 1.86 kg/HDD (Stage 2)—a decrease of 17.5%.

The catalyst lightoff time percentage ranged from 58.6% to 87.2%, with a mean lightoff percentage of 77.3%. However, catalyst lightoff time is not a good indicator of emission performance when there is a failure(s) of the emission control system of the stove. The 58.6% catalyst lightoff time percentage figure was recorded in sampling period 9 where warmer weather may have influenced the homeowner's operation of the stove. The lowest burn rate observed in this home (1.48 kg/hr) was recorded also during sampling period 9.

The observed creosote deposition was also significantly reduced from 1.48 g/HDD (Stage 1) to 1.11 g/HDD (Stage 2). There was no recorded use of alternative heating during the sampling periods.

An inspection of the Blaze King "King" catalytic stove used in home W07 was conducted on August 4, 1987. Present during the inspection were representatives from OMNI Environmental Services, Inc., Woodcutters Manufacturing, Inc. (manufacturer of the Blaze King stoves), and Griffith's Heating & Service Ltd. (installers of the stove). A detailed inspection of the entire emission control system was conducted which included the catalyst, the bypass damper mechanism, the thermostat control system, the primary, secondary and tertiary air supply systems, and all gaskets.

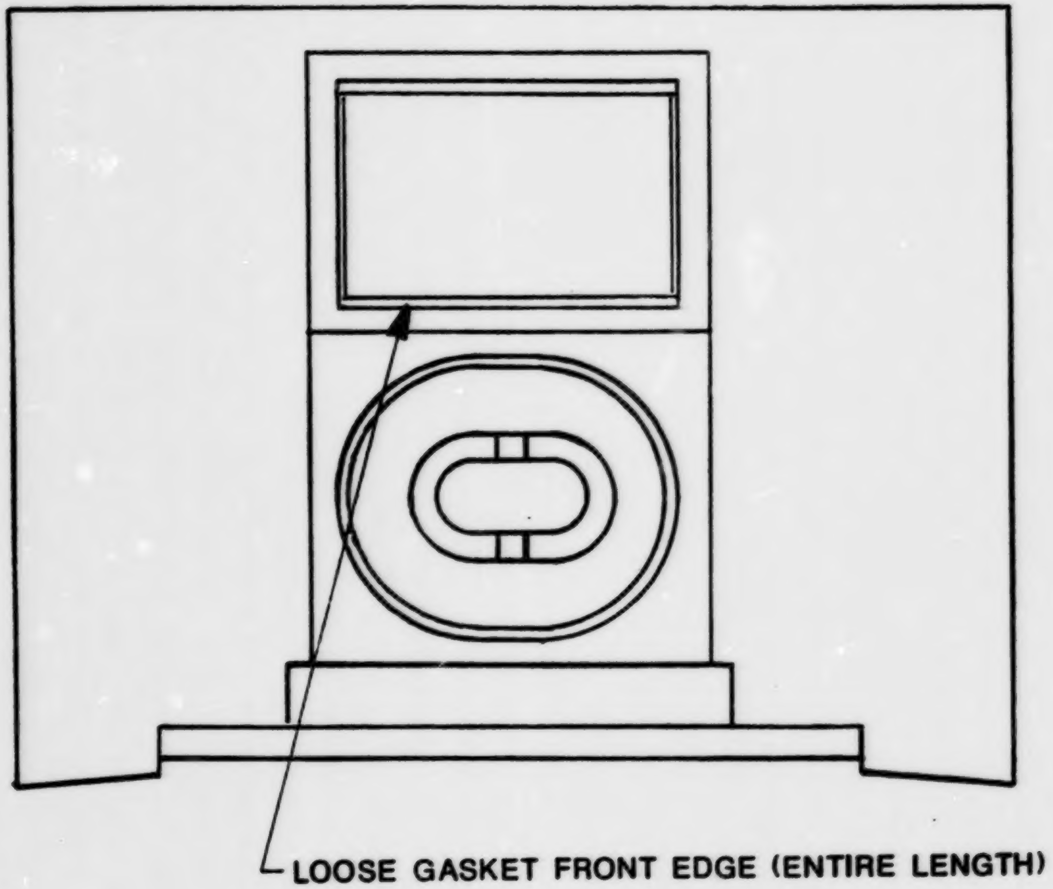
After removal of the flue pipe the bypass door assembly was inspected. Approximately 5.1 cm (2 in) of creosote and ash had built up behind the bypass door. However, the creosote-like material did not appear to be interfering with the operation of the bypass door mechanism. Using a 250-watt flood light, a light leak check was conducted to determine if light was leaking around the bypass damper door gaskets. No light leakage was observed. The bypass door was then carefully opened to inspect the condition of the gaskets used to form a seal around the bypass door. An impression was observed on all four sides of the bypass door gasket, indicating the door was sealing against the gasket. The color of the gasket in the impression area was white, indicating that combustion gases were not escaping by the gasketing material. However, it was discovered that the front edge of the gasket (i.e., gasket closest to the catalyst) was loose. No ash or other material was found on the bottom edge of the loose gasket. However, the loose gasket is considered a potential problem in that combustion gases could ultimately escape around the bypass damper door gaskets, if they are not properly sealed. Figure 4 shows the location of the loose gasket.

An inspection of the welds on the bypass damper door was also conducted. Two weld gaps, each approximately 0.238 cm ($^3/_{32}$ in) in length were observed. Figure 5 shows the location of the weld gaps. An inspection of the gasket material in the vicinity of the weld gaps did not reveal any indication of the escape of combustion gases through the weld gaps.

The thermostat assembly was removed from the stove and inspected. It was discovered that a set screw which determines the amount of tension on the bimetallic thermostat coil was improperly set according to drawings approved as part of the Oregon stove certification process. As shown in Figure 6, the set screw should be 180° from the stop (View CC) when the top surface of the air intake flipper is flush with the thermostat housing (View AA). As shown in View CC of Figure 6, the set screw was approximately 90° from the "stop" position when the air intake flipper was flush with the top of the thermostat housing. The effect of this improper screw set point was to allow a higher heat output than could be achieved under certification specifications. The incremental increase in heat output could not be determined within the scope of this study.

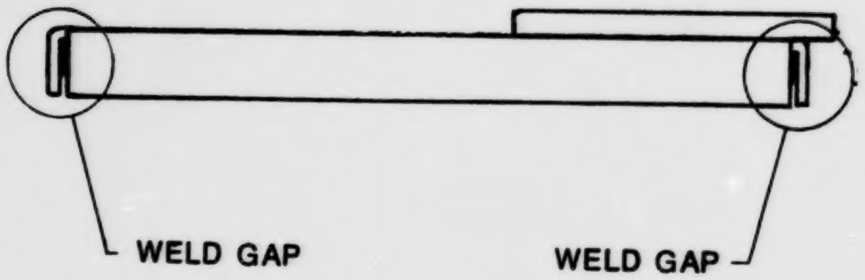
The next part of the emission control system that was inspected was the catalyst. The secondary air tube assembly was carefully removed so that a light leak check of the Interam^{TM} gasket around the catalyst could be conducted. Due to the design of the Blaze King "King" it was possible only to light leak check the back edge (nearest the catalyst access flap) of the gasket around the catalyst. No light leakage was observed. A small amount of gray ash on the bottom face (facing the firebox) was observed, but there appeared to be no blockage of the catalyst cells.

The catalyst was carefully removed to observe the condition of the Interam^{TM} gasket around the front and sides of the catalyst. A 2.54 cm (1 in) × 0.32 cm ($^1/_8$ in) gap was observed on the front side of the catalyst. It appeared that the Interam^{TM} gasket had not been overlapped at this point and most likely had been "butt" (flush end-to-end) seamed. Thermal expansion tests conducted by


LOOSE GASKET FRONT EDGE (ENTIRE LENGTH)

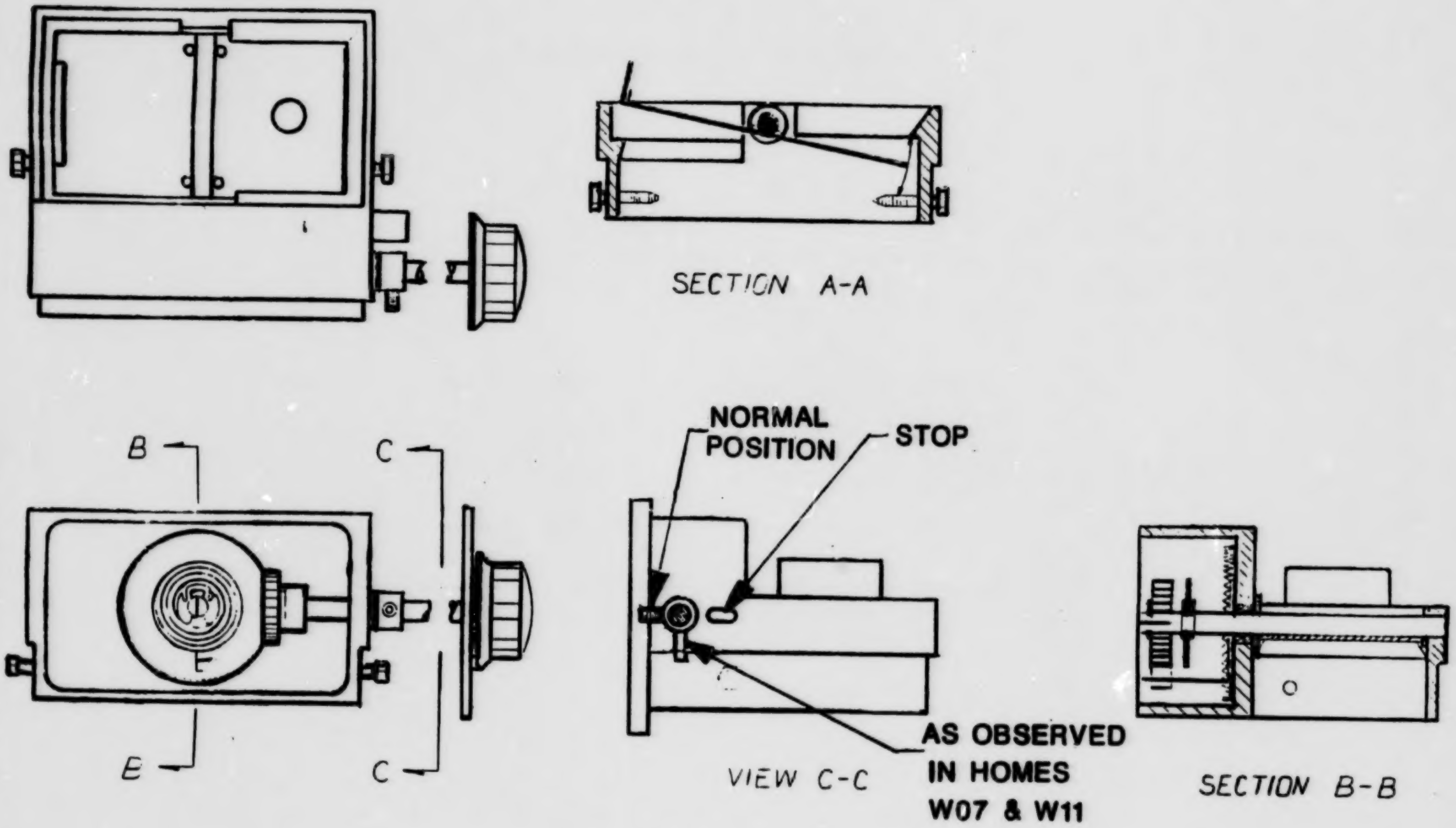
BY PASS DOOR GASKET–BLAZE KING

FIGURE 4


WELD GAP
WELD GAP

BY PASS DOOR ASSEMBLY

FIGURE 5


SECTION A-A
B
E
C
C
NORMAL POSITION
STOP
AS OBSERVED IN HOMES W07 & W11
VIEW C-C
SECTION B-B

STOVE THERMOSTAT ASSEMBLY

FIGURE 6

OMNI with Interam^{TM} gasket material indicates it will expand to fill voids, creating gaps where butt seams are located. It is therefore hypothesized that a butt seam created the observed gap. An inspection of the color and materials deposited on the metallic ring that welds the ceramic catalyst confirmed that combustion gases were escaping through the observed gap in the gasket.

A smaller diagonal "hairline" gasket gap was also discovered on the side of the catalyst where the Interam^{TM} gasket had been overlapped. Again, discoloration of the metallic ring around the catalyst confirmed the escape of combustion gases at this location.

Upon removal of the catalyst from the stove it was discovered that the catalyst was manufactured by Matsushita Battery Company of Japan (distributed by Technical Glass Products, Model Number 86–04 F8). This was an unexpected finding, since the City of Whitehorse had requested Corning "Long Life" catalysts be installed in each of the Blaze King "King" stoves. The Technical Glass Products (TGP) catalyst was shipped to OMNI's laboratory for further testing. The TGP catalyst was replaced by a Corning "Long Life" catalyst.

The catalyst removed from the stove in home W07 was tested in accordance with the Oregon Department of Environmental Quality (DEQ) "Standard Methods for Measuring the Emission and Efficiency of Woodstoves," dated June 8, 1984, and the Environmental Protection Agency (EPA) 40CFR Part 60, Subpart AAA—Standard of Performance for Residential Wood Heaters as published for comment on Wednesday, February 19, 1987. Stove emissions were measured using the Dilution Tunnel Method (EPA Method 5G). The testing was performed between August 13 and 25, 1987, at OMNI's Solid Fuels Testing Laboratory in Beaverton, Oregon. Detailed test results are found in Appendix E of this report.

The initial objective of the laboratory testing was to evaluate the performance of the TGP catalyst under a heat output condition that simulated average heat output conditions as determined from the data from homes W07 and W11. Based on an analysis of burn rates (kg [dry]/hr), the higher heating value of the "firekilled" and "seasoned" fuels used in Whitehorse, and the average overall efficiency of the Blaze King "King" stoves, it was determined the average heat output was 19,000 Btu per hour.

At the request and sponsorship of Woodcutters Manufacturing, Inc., four additional laboratory tests were added to cover the full range of heat outputs from the Blaze King "King" stove. The request for additional tests from Woodcutters was approved by the City of Whitehorse and Energy, Mines and Resources Canada with the provision that all data collected would be included in this report.

Table 21 shows a summary of the results from five test runs on the catalytic combustor from home W07. Using a frequency distribution of burn rates (heat outputs) from home W07, a weighted emission rate was calculated from the data in Table 21. The home W07 weighted emission rate is 10.1 g/hr. The mean emission rate for Stage 2 in home W07 was 15.3 g/hr, and the Oregon

TABLE 21

EMISSION PERFORMANCE—BLAZE KING "KING" WITH CATALYST FROM HOME W07

Particulate Emissions (g/hr)	Burn Rate (kg [dry]/hr)	Heat Output (Btu/hr)	Overall Efficiency (%)
18.6	0.91	10,890	61.9
11.8	1.07	14,062	68.1
9.4	1.38	17,836	66.9
11.8	2.34	29,920	66.1
16.6	2.82	34,802	63.9

Estimated weighted particulate emission rate for heat output distribution in home W07: 10.1 g/hr.

certification weighted emission rate for the Blaze King "King" was 1.6 g/hr. This data implies that approximately 70% of the elevated emission rates in sampling periods 8 and 9 could be attributed to catalyst performance while the remaining 30% to factors such as combustion gas leakage around catalyst gaskets and possibly operator practices, e.g., frequency of use of bypass damper and maintenance of catalyst light-off conditions. However, the improper setting of the bimetallic coil thermostat may have contributed to premature reduction in catalyst performance due to overheating. It is impossible to determine the sequence of emission control system failure leading to the marked increase in emission rates between sampling periods 6 and 8.

Table 22 shows a frequency distribution of in-catalyst temperatures during the study. According to a representative of the catalyst distributor, extended in-catalyst temperature exposures exceeding 871°C (1600°F) are viewed as an undesirable condition[8]. Table 22 indicates 46.2 hours of in-catalyst temperatures exceeding 871°C (1600°F) during the study.

It appears no single contributing factor has resulted in the elevated emission rates observed in home W07. Discussions with the manufacturer have indicated a number of actions have been initiated to correct the manufacturing problems observed. A summary of the corrective actions is listed in a copy of a letter to Larry Canaday dated September 23, 1987, found at the end of Appendix E.

Home W08

Stage 1: RSF "65"

Stage 2: Uni-Com Catalytic Damper

Mean gram per hour particulate emission rates were significantly reduced from 28.5 g/hr (Stage 1) to 15.0 g/hr (Stage 2) after installation of the new woodheat technology. Mean burn rate was also significantly reduced from 1.59 kg/hr (Stage 1) to 1.38 kg/hr (Stage 2). Mean overall efficiency was increased from 44.0% to 53.5%. Wood usage decreased from 1.42 kg (dry)/HDD (Stage 1) to 1.28 kg (dry)/HDD (Stage 2)—a 9.6% reduction.

The observed creosote deposition increased from 0.85 g/HDD (Stage 1) to 0.92 g/HDD (Stage 2); however, the uncertainty associated with the creosote collection method indicates that the difference between the Stage 1 and Stage 2 creosote deposition data may be misleading.

Catalyst lightoff time percentages ranged from 18.9% to 59.9%, with a mean lightoff percentage of 40.3%. This home had one of the lower mean catalyst lightoff time percentages for the homes with the catalytic retrofits. Although the catalytic retrofit did reduce emissions and burn rates and increased overall efficiency, the mean catalyst lightoff time percentage for home W08 was slightly lower than the mean lightoff percentage of 41.1% for all catalytic retrofits.

Some smoke spillage was experienced; however, the installation of a smoke retainer flap near the stove door reduced the smoke spillage problem. Alternative heat use increased slightly during the coldest measured sampling period (6).

TABLE 22

IN-CATALYST TEMPERATURE FREQUENCY DISTRIBUTION—HOME W07

```
----------------------------------------------------------------------------------------
File           : W07.TCD

FO Date/Time   :  9/1/87  12:58

Data collected: 01/30/87 1755  to  04/07/87 1430

TC # 2    (Catalyst Temperature)
 ** based on "15 minute" averages (high and low values not included) **
----------------------------------------------------------------------------------------

Avg Temp          Hours        Frequency        Cumulative Frequency
(deg. F)          Total           (%)                   (%)

----------------------------------------------------------------------------------------
 100 -   199       54.0            3.7                    3.7
 200 -   299       70.5            4.8                    8.4
 300 -   399       70.7            4.8                   13.2
 400 -   499       70.2            4.8                   18.0
 500 -   599       77.7            5.3                   23.3
 600 -   699      100.0            6.8                   30.1
 700 -   799      120.0            8.1                   38.2
 800 -   899      151.2           10.3                   48.5
 900 -   999      177.7           12.1                   60.5
1000 -  1099      171.2           11.6                   72.2
1100 -  1199      136.0            9.2                   81.4
1200 -  1299       91.7            6.2                   87.6
1300 -  1399       59.5            4.0                   91.6
1400 -  1499       38.0            2.6                   94.2
1500 -  1599       39.0            2.6                   96.9
1600 -  1699       30.5            2.1                   98.9
1700 -  1799       14.2            1.0                   99.9
   1800+            1.5            0.1                  100.0

----------------------------------------------------------------------------------------
Total Number of Points
  ("15 minute" averages):    5896
Mean Average Temperature:  883 degrees F   (SD= 374 degrees F)
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Home W09

Stage 1: Energy King "King" (non-catalytic)

Stage 2: Osburn "Imperial 2000"

The Stage 1 conventional technology woodstove had a mean emission rate of 15.7 g/hr, which is relatively low for a conventional technology woodstove. The Stage 2 woodstove had a mean emission rate of 19.0 g/hr, which is significantly higher than the mean emission rate of 9.6 g/hr for the same stove model in home W04.

Mean burn rate was slightly decreased from 0.99 kg/hr (Stage 1) to 0.93 kg/hr (Stage 2), a difference which is probably insignificant. Overall efficiency decreased from 55.9% (Stage 1) to 45.4% (Stage 2). The relatively high overall efficiency in Stage 1 is due to the high heat transfer efficiency component of the overall efficiency calculation. Wood usage increased from 0.84 kg (dry)/HDD (Stage 1) to 0.91 kg (dry)/HDD (Stage 2)—an increase of 9.0%. The observed creosote deposition was significantly decreased from 1.28 g/HDD (Stage 1) to 0.49 g/HDD (Stage 2).

The homeowner indicated that the heat output from the Stage 2 woodstove was insufficient. Prior to sampling period 6, the flue pipe diameter was reduced from 20.3 cm (8 in) to 15.2 cm (6 in). The original packed flue pipe was replaced with single wall flue pipe from the flue collar to the ceiling thimble. According to the homeowners, heat output was improved; however, no change in emission rates or overall efficiency was discernable after the chimney system change. The homeowner indicated that although the heat output had been improved it was still insufficient to fulfill heating demand needs. Alternative heat use indicates no use of supplementary heat during the measured sampling period of Stage 2.

An inspection of the "Imperial 2000" stove in home W09 was conducted on August 4, 1987. All accessible sections of the emission control system were inspected. It was observed that the air inlet slider opening (source of primary and secondary air) in the full closed position was 0.635 cm (0.25 in). According to certification drawings, the minimum opening in the full closed position should be 1.11 cm (0.437 in). The air inlet slider opening in the full open position was 5.87 cm (2.31 in) as compared to certification requirements of 6.35 cm (2.5 in). The baffle plate just above the secondary air intake was warped in the center section, slightly reducing the cross sectional area where exiting combustion gases enter the flue collar. An inspection of the identical stove model in home W04 on August 5, 1987 found the same conditions regarding air inlet slider openings and warped baffle. However, as indicated in Table 15 the mean gram per hour emission rate for home W09 was 19.0 versus 9.6 for W04—an increase of 98%. The only significant difference that could be determined between the two homes is the configuration of the chimney system. A detailed description of each chimney system is found in Appendix F.

It is hypothesized that the type of chimney system used in home W09 may be a contributing factor to the observed elevated emission rates. The relatively short length 3.4 m (11.2 ft) of the chimney coupled with the mismatching of a 15 cm (6 in) diameter flue pipe with 20 cm (8 in) packed pipe may be resulting in relatively poor draft conditions and thereby influencing the combustion efficiency of the stove. The manufacturer of the stove recommends a uniform run of 15 cm (6 in) diameter pipe. Independent testing of the Osburn "Imperial 2000" under laboratory test conditions would be needed to confirm if the chimney configuration in home W09 is a major factor influencing emission performance. It was beyond the scope of this study to determine the performance of certified non-catalytic stoves with different chimney configurations.

Home W10

Stage 1: Fisher "Mama Bear"

Stage 2: Double Wall Flue Pipe

The mean particulate emission rate with the Security double wall flue pipe system with the vented airspace was 30.7 g/hr. The mean emission rate with the James A. Ryder double wall flue pipe system with the sealed airspace was 24.1 g/hr. The mean emission rate in Stage 1 was 23.1 g/hr.

Overall mean efficiency was slightly decreased from 50.5% (Stage 1) to 45.7% (Stage 2); however, statistical analysis indicates that there is a 30% to 40% probability that the means are statistically the same.

The mean burn rate observed in Stages 1 and 2 does not differ significantly—1.34 kg/hr in Stage 1, 1.36 kg/hr in Stage 2. Wood usage decreased from 1.30 kg (dry)/HDD (Stage 1) to 1.26 kg (dry)/HDD (Stage 2)—a decrease of 3.0%. The observed creosote deposition appears to be significantly lower with the double wall flue pipe in place; however, a missing creosote sample in the Stage 2 creosote data set makes the Stage 2 figure highly questionable, even though the creosote data was normalized.

The homeowner did not observe the kind of rapid creosote buildup observed in home W01 with the vented double wall flue pipe. However, it was observed that the lower half of the vented flue pipe became "cherry" red on February 16, 1987. Upon removal of the flue pipe, the homeowner reported burning creosote in a section of the vented flue pipe. According to the homeowner he had never experienced this problem with the single wall pipe used in Stage 1 or after the vented double wall pipe was replaced with sealed double wall pipe in Stage 2.

There was a slight increase (7.6 hours) of alternative heat use in sampling period 2 as compared to all other periods. However, this was not the coldest sampling period measured and the reason for this increase cannot be explained.

Home W11

Stage 1: RSF "65"

Stage 2: Blaze King "King"

The mean particulate emission rates decreased from 16.8 g/hr (Stage 1) to 15.6 g/hr (Stage 2); however, statistical comparison of the mean emission rates indicates that the rates have a 70% to 80% probability that they are not different.

Mean burn rate was significantly reduced from 2.25 kg/hr (Stage 1) to 1.71 kg/hr (Stage 2), and overall efficiency was slightly improved from 51.1% (Stage 1) to 56.5% (Stage 2). Wood use decreased from 2.04 kg (dry)/HDD (Stage 1) to 1.91 kg (dry)/HDD (Stage 2)—a decrease of 5.9%. The lower efficiency observed for the RSF "65" in sampling periods 2 and 3 is probably due to more cold-to-cold burn cycles (i.e., less stove use) during these periods. The observed creosote deposition did not significantly change in Stages 1 (0.51 g/HDD) and 2 (0.52 g/HDD).

Catalyst lightoff time percentages ranged from 57.2% to 85.0% with a mean lightoff percentage of 69.6%. The lower catalyst lightoff time percentages observed in this home occurred during sampling periods recorded during relatively warm weather. The mean catalyst lightoff time percentage in home W11 was close to the 73.2% mean catalyst lightoff time percentage for all integral catalytic woodstoves in the study. There was no recorded use of alternative heat during the sampling periods.

An inspection of the Blaze King "King" catalytic woodstove used in home W11 was conducted on August 5, 1987. Present during the inspection were representatives from OMNI Environmental Services, Inc., Woodcutters Manufacturing, Inc., and Griffith's Heating & Service Ltd. As in the case with the stove in home W07, a detailed inspection of the entire emission control system was conducted.

There was approximately 5.1 cm (2 in) of creosote and ash built up behind the bypass door. This material did not appear to be interfering with the operation of the bypass door mechanism. However, the catalyst access flap (rectangular piece of sheet metal) was found wedged behind the bypass door hinge. Discussion with one of the homeowners indicated that the bypass lever mechanism was difficult to operate in the beginning of the study, but it was attributed to "breaking in" a new stove. Unfortunately, the problem with the bypass lever was never reported to the field technicians. It is hypothesized that the catalyst access flap was jarred loose during the movement of the stove from the dealer to home W11. The catalyst access flap is held by two small tabs. It appeared that the tabs were not bent at the correct angle to ensure that the catalyst access flap was securely fastened.

With the catalyst access flap missing, combustion gases were directly vented to the flue pipe rather than passing through the heat exchanger of the stove. This observation could partially explain the differences in mean overall efficiency between home W11 (56.5%) and home W07 (60.6%), where the catalyst access flap was properly installed. A light leak check of the bypass door gasket did not show any light leakage. The bypass door was opened to inspect the condition of the gasket. An impression was observed on all four sides of the bypass door gasket indicating the door was sealing against the gasket. The color of the gasket in the impression area was white indicating that combustion gases were not escaping by the gasket. However, as found with the Blaze King "King" stove in home W07, the front edge (i.e., edge nearest catalyst) of the gasket was loose. It appeared the adhesive (according to the manufacturer—high temperature silicone adhesive) had been vaporized.

Two weld gaps approximately 0.238 cm ($^3/_{32}$ in) in length were found in the bypass door corners. However, a close inspection of the gasket in the vicinity of the weld gaps did not reveal any indication of the escape of combustion gases through the weld gaps.

The thermostat assembly was removed from the stove and inspected. As found in the stove in home W07, the set screw which controls the amount of tension on the thermostat bimetallic coil was not set in the position as specified in the Oregon emission certification drawings. The set screw position was identical to that found on the stove in home W07.

An inspection of the catalyst gasket revealed that the catalyst was not properly positioned in the catalyst combustor seat. The catalyst was "tipped" so that the right side (side nearest bypass lever) of catalyst was approximately 1.58 cm ($^5/_8$ in) below the combustor seat. A light leak test confirmed that the catalyst was not properly seated, and that the Interam™ gasket around the catalyst was not properly sealed. An inspection of the color and material deposited on the metallic ring ("can") that holds the ceramic catalyst confirmed that combustion gases were escaping by the catalyst. It is hypothesized that the unseating of the catalyst occurred during the movement of the stove from the stove dealer's warehouse to home W11, since OMNI staff verified that the catalyst was properly seated in the dealer's warehouse prior to installation.

The catalyst in the stove was also manufactured by Matsushita Battery Company of Japan (distributed by Technical Glass Products [TGP]—model 86–04 F8). This catalyst was also shipped to OMNI's Beaverton, Oregon laboratory for further testing.

An attempt was made to replace the TGP catalyst with a Corning "Long Life" catalyst. However, the combustor holder seat was 0.48 cm ($^3/_{16}$ in) too small to hold the replacement catalyst. A check of the certification drawings confirmed that the combustor holder was undersized for a standard size replacement catalyst. The stove manufacturer claims the combustor seat was most likely warped due to a "hot spot" being created by the misaligned catalyst and represents an anomalous situation. The undersized or warped catalytic combustor sent represents a potential problem to the consumer desiring to replace a catalyst, since the combustor holder is welded into the stove. Without replacing or modifying the combustor holder, the consumer would have to special order a custom sized catalyst to fit into their particular stove.

The catalyst removed from the stove was tested in accordance with the methods used to evaluate the catalyst in the Blaze King "King" stove in home W07. The testing was performed on August 19, 1987, at OMNI's Solid Fuels Testing Laboratory in Beaverton, Oregon. Detailed test results are found in Appendix E of the report.

A single test was performed on the catalyst from home W11. Table 23 shows a summary of the results of the test. For purposes of comparison, the laboratory test results from the catalysts used in

TABLE 23

EMISSION PERFORMANCE—BLAZE KING "KING" WITH CATALYST FROM HOME W11

Particulate Emissions (g/hr)	Burn Rate (kg [dry]/hr)	Heat Output (Btu/hr)	Overall Efficiency (%)
10.8	1.56	21,057	70.1

homes W07 and W11, and the original certification test results, are shown in Figure 7. Without completing a full heat output range of tests, it is not possible to determine the performance curve for the catalyst in home W11. However, the single test value of 10.8 g/hr at a heat output of 21,057 Btu/hr indicates a significant decrease in catalyst performance.

Table 24 shows a frequency distribution of in-catalyst temperatures. This table also shows 28.5 hours of in-catalyst temperatures exceeding 871°C (1600°F). As previously discussed, this is viewed as an undesirable situation by the catalyst distributor (Technical Glass Products) and may be a contributing factor to a decrease in catalyst performance. While a premature decrease in catalyst performance is probably a significant contributing factor to the elevated emission rates observed in home W11, the unseated catalyst must also be considered a significant contributing factor. The consistent measured elevated emission rates for all of the Stage 2 sampling periods would tend to support this hypothesis as compared to the pattern observed in home W07 (i.e., only last two sampling periods having significantly elevated emission rates).

Home W12

Stage 1: Fisher "Papa Bear"

Stage 2: Nu-Tec Catalytic Retrofit

Mean particulate emission rates were significantly reduced from 25.3 g/hr (Stage 1) to 16.6 g/hr (Stage 2). The mean burn rate was reduced from 1.63 kg/hr (Stage 1) to 1.52 kg/hr (Stage 2) and mean overall efficiency was increased from 52.5% (Stage 1) to 56.0% (Stage 2).

During sampling period 6 the before-catalyst emission rate was 15.8 g/hr, and the after-catalyst emission rate was 15.2 g/hr. Review of the data set for each sampling location during sampling period 6 did not indicate any anomalies that would influence the emission calculations. This relatively small emission rate reduction difference may be due to the operator learning to operate the Nu-Tec.

Catalyst lightoff time percentages ranged from 28.0% to 60.6%, with a mean catalyst lightoff time percentage of 45.8%. The lower catalyst lightoff time percentages were recorded during sampling periods 8 and 9 when the weather was relatively warm. For some undetermined reason, there was no demonstrated change in wood use between Stage 1 and Stage 2, despite the decrease in burn rate and increase in overall efficiency.

Observed creosote deposition increased from 0.81 g/HDD (Stage 1) to 1.04 g/HDD (Stage 2).

The homeowner experienced problems with smoke spillage after the catalytic retrofit installation; however, the data indicates that the device was effective at increasing overall efficiency while reducing both particulate emissions.

Smoke spillage was observed from the chimney system connections, the Nu-Tec unit housing, and the stove door when refueling. The chimney connections were sealed with stove cement, which eliminated this source of smoke spillage. The homeowner observed that the smoke spillage from the

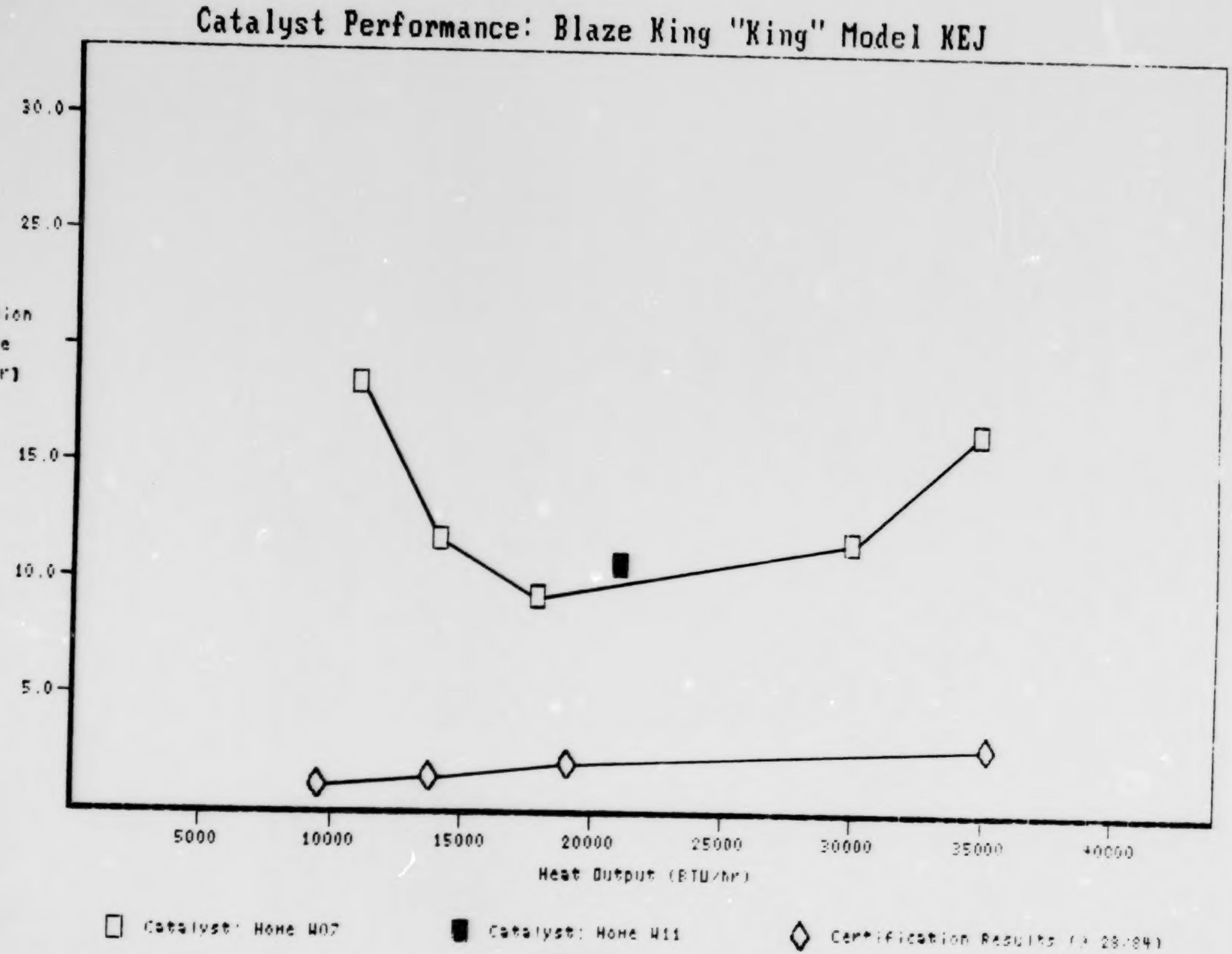
Catalyst Performance: Blaze King "King" Model KEJ
Emission Rate (g/hr)
30.0
25.0
15.0
10.0
5.0
5000
10000
15000
20000
25000
30000
35000
40000
Heat Output (BTU/hr)
☐ Catalyst: Home W07
■ Catalyst: Home W11
◇ Certification Results (3/28/84)

FIGURE 7

TABLE 24

IN-CATALYST TEMPERATURE FREQUENCY DISTRIBUTION—HOME W11

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----------------------------------------------------------------------------
File          : W11.TCD

PO Date/Time  :  9/1/87  13:11

Data collected: 02/02/87 1705  to  04/13/87 1415

TC # 2   (Catalyst Temperature)
 ** based on "15 minute" averages (high and low values not included) **
----------------------------------------------------------------------------

Avg Temp        Hours        Frequency      Cumulative Frequency
(deg. F)        Total           (%)                 (%)
----------------------------------------------------------------------------
 100 -  199     187.7          13.7                13.7
 200 -  299     101.5           7.4                21.1
 300 -  399      74.2           5.4                26.5
 400 -  499      59.0           4.3                30.8
 500 -  599      70.7           5.2                36.0
 600 -  699      88.0           6.4                42.4
 700 -  799     114.2           8.3                50.7
 800 -  899     137.0          10.0                60.7
 900 -  999     134.0           9.8                70.4
1000 - 1099     112.7           8.2                78.7
1100 - 1199      91.0           6.6                85.3
1200 - 1299      66.0           4.8                90.1
1300 - 1399      42.7           3.1                93.2
1400 - 1499      35.0           2.6                95.8
1500 - 1599      29.5           2.2                97.9
1600 - 1699      21.7           1.6                99.5
1700 - 1799       6.0           0.4                99.9
   1800+          0.8           0.1               100.0

----------------------------------------------------------------------------
Total Number of Points
  ("15 minute" averages):   5488
Mean Average Temperature:  755 degrees F   (SD= 418 degrees F)
```

Nu-Tec unit housing occurred when a fire had been lit in a cold stove and adequate draft had not been established prior to engaging the catalyst. Despite efforts to improve draft conditions prior to fuel loading, e.g. setting high air draft setting prior to loading, no effective technique could be developed for reducing the smoke spillage from the stove door during fuel loading events.

Home W13

Stage 1: Sears "Automatic"

Stage 2: Pacific Energy Systems "Super 27" (uncertified version)

The mean particulate emission rates were significantly reduced 29.9 g/hr (Stage 1) to 21.6 g/hr (Stage 2). The Stage 2 technology had a mean particulate emission rate that was lower than the Stage 1 conventional technology; however, the Stage 2 mean particulate emission rate was comparable to several conventional technology stoves evaluated in this study. Sampling period 5 (the first sampling period completed with the "Super 27") produced an emission rate of 33.2 g/hr, which was the highest observed in any sampling period in this home. This observation could indicate that during this sampling period the homeowner was still learning to operate the new woodstove. The pins that hold the baffle assembly in place on the "Super 27" were mounted incorrectly, which caused the baffle plate to detach and fall into the firebox; however, this problem was corrected by the homeowner prior to the start of sampling period 5. If sampling period 5 is not included, the mean particulate emission rate for Stage 2 is 18.7 g/hr, which is significantly lower than the Stage 1 mean gram per hour emission rate, and is similar to the 15.7 g/hr mean emission rate observed on the same stove model in home W06.

Mean burn rate was significantly decreased from 1.80 kg/hr (Stage 1) to 1.12 kg/hr (Stage 2). The observed creosote deposition increased from 0.26 kg/HDD (Stage 1) to 1.22 kg/HDD (Stage 2). A similar creosote deposition rate increase was observed for the "Super 27" in home W06.

Mean overall efficiency was slightly increased from 48.4% (Stage 1) to 50.0% (Stage 2); however, statistical comparison indicates that this increase is probably not significant. There was a significant decrease in wood use between Stage 1 (1.92 kg [dry]/HDD) and Stage 2 (1.11 kg [dry]/HDD). However, a significant contributing factor to the difference in wood use rates is attributable to differences in firebox size between the Sears "Automatic" and the PES "Super 27."

The only noticeable increase in alternative heat usage occurred during the coldest observed sampling period (7).

An inspection of the Pacific Energy Systems (PES) "Super 27" stove used in home W13 was conducted on August 5, 1987. As found with the woodstove in home W06, it was discovered the "Super 27" in home W13 was an uncertified model. The same type of safety listing label was found on the stove indicating an "Oregon certified" version was available from the manufacturer.

Home W14

Stage 1: RSF "65"

Stage 2: Burning Log "Turbo 10"

The mean particulate emission rate was reduced from 27.8 g/hr in Stage 1 to 8.8 g/hr in Stage 2.

The mean burn rate was significantly reduced from 1.25 kg/hr (Stage 1) to 1.01 kg/hr (Stage 2) and mean overall efficiency was increased from 37.5% (Stage 1) to 52.1% (Stage 2). Wood use decreased from 1.19 kg (dry)/HDD (Stage 1) to 1.03 kg (dry)/HDD (Stage 2).

Catalyst lightoff time percentages ranged from 57.3% to 78.8%, with a mean lightoff percentage of 68.1%. The relatively narrow range of catalyst lightoff time percentages indicates that the "Turbo 10" performed in a consistent fashion in this home. The mean catalyst lightoff time percentage was slightly lower than the overall mean of 70.8% for all integral catalytics; however, it was virtually identical to the mean catalyst lightoff time percentage of 69.5% recorded on the "Turbo 10" in home W03. The observed creosote deposition was significantly reduced from 1.56 g/HDD (Stage 1) to 0.65 g/HDD (Stage 2).

The homeowner was satisfied with the heat output from the Stage 2 stove; however, the 8-hour burn time between refuelings was not sufficient to meet the homeowner's fueling needs. The conventional technology stove was reinstalled at the conclusion of the study at the request of the homeowner.

An inspection of the catalysts and the gasket below the catalyst was conducted by a representative of Energy, Mines and Resources Canada and Griffith's Heating & Service Ltd. on September 24, 1987. A single strip of gasketing material was located in front of the lower support bracket and was not friction fitted as in the case of the "Turbo 10" in home W03. The gasket and both of the catalysts appeared to be in good condition, i.e. no visible gaps. The catalysts were manufactured by Corning (Model 6000—serial numbers 9048110 and 9048358) and were replaced by new Corning catalysts.

VII. STUDY PARTICIPANT COMMENTS REGARDING NEW WOODHEAT TECHNOLOGIES

One of the primary study objectives was to observe the operation of the new technology devices under "in home" conditions. The study participants provided feedback on the characteristics of the devices which helped with an overall evaluation of each of the new woodheat technologies. At the conclusion of the study exit interviews were conducted with each homeowner. Appendix F lists a profile of each study home, including Stage 1 and Stage 2 woodstove systems, home characteristics, and participant comments. The participant comments and observations regarding the operation of the new technology devices are summarized as follows:

A. Double Wall Flue Pipe

The double wall flue pipe was installed in homes W01 (RSF "65") and W10 (Fisher "Mama Bear"). The vented Security pipe was installed first and monitored for sampling periods 5 and 6 in home W01 and sampling periods 5, 6, and 7 in home W10. Study participants in home W01 felt that the stove had better draft with the Security pipe; however, a rapid creosote buildup was observed in the lower 1.5 m (4.9 ft) of flue pipe. The creosote buildup also contributed to smoke spillage problems. Occupants in home W10 did not notice any change in stove performance after the Security double wall pipe installation.

The James A. Ryder double wall flue pipe was installed for sampling periods 7, 8, and 9 in home W01 and sampling periods 8 and 9 in home W10. Study participants in either home could not detect any change in stove performance after the installation of the James A. Ryder flue pipe.

B. Pacific Energy Systems "Super 27" (uncertified version)

The "Super 27" was installed in homes W06 and W13. Study participants in home W06 felt that the stove's heat output was inadequate for their installation. According to the study participants in home W06, the heat output was sufficient for outdoor temperatures above −10°C (14°F), otherwise heat output was insufficient. The homeowners in home W06 were unsatisfied with several design characteristics of the stove also. Comments that occupants in home W06 made regarding the unsatisfactory characteristics of the "Super 27" included:

1. Burn time is too short—stove would burn for four to six hours maximum between refuelings.
2. Some smoke spillage was observed when loading fuel.
3. Firebox did not have sufficient room to contain ash/coalbed. Ash would spill when the fuel loading door was opened.
4. Fuel length must be less than 30 cm (12 in).
5. Homeowner felt that fuel consumption was higher than with their Energy King "Princess" conventional technology woodstove.
6. The cable connecting the draft control to the air intake was broken during the study and the air intake was operated manually for 20 days while waiting for repair parts.

Occupants in home W13 were generally pleased with the performance of the "Super 27." The homeowner thought that the 30 cm (12 in) fuel length requirement was inconvenient, but heat output and burn times between refuelings were sufficient. It should be noted that home W13 is a mobile home with 70 m^2 (750 ft^2) of floor area to heat versus 186 m^2 (2000 ft^2) for home W06. Study participants in home W13 felt that fuel consumption was much lower than with the Sears "Automatic" conventional technology woodstove. In home W13 the baffle assembly at the top of the firebox of the "Super 27" detached after the stove installation and dropped into the firebox. Subsequent inspection of the woodstove revealed incorrectly installed pins that hold the baffle assembly in place. The baffle assemble was reinstalled with the pins correctly relocated. No additional mechanical problems were reported after this repair was completed.

C. Osburn "Imperial 2000"

The "Imperial 2000" was installed in homes W04 and W09. Occupants in home W04 were generally pleased with the performance of the stove. The homeowners noted that 4 to 6 hours was the maximum burn time under high heat demand conditions. The participants in home W04 were surprised by the heating ability of the stove under most heating conditions; however, they thought the woodstove was undersized for heating under the coldest winter conditions. When the stove was initially installed the participants felt that it was undersized for the home. The homeowners did note that the performance in terms of heat output and burn time between refuelings of the "Imperial 2000" was roughly equivalent to the conventional technology Sears "Automatic"; however, the "Imperial 2000" appeared to use less fuel for an equivalent heat output.

Home W09 felt that the heat output from the "Imperial 2000" was insufficient. The flue pipe connected to the stove when it was first installed was 20 cm × 25 cm (8 in × 10 in) packed pipe, which was later replaced with 15 cm (6 in) single wall pipe. The homeowners felt that the flue pipe change had increased the heat output from the stove, but was still insufficient. The study participants in home W09 felt that the 5-hour maximum burn time between fuelings was too short.

D. Nu-Tec Catalytic Retrofit

The Nu-Tec was installed in homes W02 (RSF "65") and W12 (Fisher "Papa Bear"). The study participants in home W02 experienced multiple episodes of smoke spillage and removed the Nu-Tec after two sampling periods. In home W02 smoke spillage occurred from the stove door when opened and from the Nu-Tec unit housing when the fuel had burned down to a glowing coalbed. The homeowner was given instructions in creating sufficient draft prior to opening the stove door. Also, the RSF bypass linkage was temporarily disconnected for approximately three days during sampling period #5, leaving the bypass open. A horizontal run of chimney was also permanently eliminated. These remedial actions did not eliminate the observed smoke spillage problem. The homeowner could not detect any change in heat output or fuel consumption resulting from the installation of the Nu-Tec and felt that more rapid creosote buildup occurred as a result of the Nu-Tec installation.

The participants in home W12 also experienced smoke spillage from the stove door when the door was open. On three occasions after the installation of the Nu-Tec the family room of the home was filled with smoke. On one of these occasions the homeowner had just lit a fire in a cold stove, engaged the catalyst, and returned a short time later to observe smoke spillage from the Nu-Tec unit housing and flue pipe fittings. It appeared that the homeowner did not allow sufficient time to establish a good draft prior to engaging the catalyst in the Nu-Tec. The homeowner noted that it was more difficult to establish an initial draft when lighting a cold stove with the Nu-Tec in place. On two other occasions the homeowners found smoke throughout the home in the early morning hours.

According to the study participants the catalytic device was spontaneously "puffing" or blowing smoke out the spin drafts of the stove. It is hypothesized this observed "puffing" was due to spontaneous ignition of unburned combustion gases. This spontaneous "puffing" of smoke from add-on devices was also reported in a field study being conducted by OMNI in the northeastern United States. The homeowner could not detect any changes in stove heat output or fuel consumption after installation of the Nu-Tec.

E. Uni-Com Catalytic Damper

The Uni-Com was installed in homes W05 (Acorn "Ranger") and W08 (RSF "65"). Home W05 occasionally observed smoke spillage from the stove door when fueling the stove. A smoke retainer flap was installed just inside the stove door; however, the flap did not reduce the smoke spillage. The homeowner could not detect any changes in stove heat output or fuel consumption after installation of the Uni-Com. At the conclusion of the study the homeowner removed the Uni-Com, primarily because of the smoke spillage problems.

Home W08 also occasionally observed smoke spillage from the stove door when fueling the stove after the Uni-Com installation. A smoke retainer flap was installed just inside the stove door, and the homeowner reported that the smoke spillage had been significantly reduced. The homeowner could not detect any change in stove heat output or fuel consumption after the Uni-Com installation. The homeowner noted that he would be pleased with the Uni-Com if it could be demonstrated that the unit was reducing fuel consumption.

F. Blaze King "King"

Blaze King "King" integral catalytic woodstoves were installed in homes W07 and W11. Study participants in home W07 were very pleased with the "King." The homeowners felt that heat output and burn times were sufficient and fuel consumption was much lower than with the conventional technology "King." The participant noted that it was sometimes difficult to establish an initial draft when lighting a cold stove. The participant found that using a larger than normal amount of paper and kindling when lighting a fire helped to warm the chimney and establish good draft conditions.

Study participants in home W11 were also very pleased with the "King's" performance. Heat output and burn times were sufficient and fuel consumption was lower than with their RSF "65." This homeowner also noted that it was difficult to establish an initial draft when lighting a cold stove. The homeowner observed some smoke spillage occasionally when fueling the stove; however, it was noted that the amount of smoke spillage was usually less than with their RSF "65" stove.

G. Burning Log "Turbo 10"

The Burning Log "Turbo 10" was installed in homes W03 and W14. Home W03 was pleased with the performance of the "Turbo 10." Heat output and the overnight burn times were sufficient. The homeowner particularly liked the convection-type heat output from this stove. The homeowner felt that the stove produced an even heating of the entire home, where previously the radiant heat from the conventional technology Fisher "Grandma Bear" tended to overheat the basement where the woodstove was installed. This homeowner also felt that the relatively warm winter in Whitehorse did not give the stove a chance to prove itself under more typical heating conditions.

Study participants in home W14 were pleased with the heat output of the "Turbo 10"; however, they felt that the maximum 8 hour burn time was not sufficient for their heating needs. Overall, the homeowners in home W14 felt that the "Turbo 10" was a very good stove, considering the relatively small firebox. The homeowner noted that at a low burn setting creosote was deposited on the glass door. The homeowner planned on replacing the "Turbo 10" at the conclusion of the study with the original RSF "65," primarily because of the longer burn time capability of the RSF.

VIII. DISCUSSION OF NEW WOODHEAT TECHNOLOGY PERFORMANCE

Table 25 lists a summary of mean gram per hour particulate emission rates by woodstove model. This table compares emission rates by stove model for conventional technology, double wall flue pipe, low emission non-catalytics, catalytic retrofits, and integral catalytics. The table also lists mean emission rates as a combined group for all models in each technology category. Table 26 presents mean overall efficiency data for each technology model. Table 27 lists a summary of wood use for each technology model.

A. Double Wall Flue Pipe

The double wall flue pipe performed in a similar manner in homes W01 and W10. The emission rates ranged from 18.0 g/hr to 33.9 g/hr in home W01 and from 21.0 g/hr to 40.5 g/hr in home W10.

The following summarizes the mean emission rates in grams per hour for the two types of double wall flue pipe in each home:

Home	Flue Pipe System	Mean Emission Rate (g/hr)
W01	Security	31.0
	James A. Ryder	22.1
W10	Security	30.7
	James A. Ryder	24.1

Wood usage significantly decreased (37.1%) in home W01 from Stage 1 to Stage 2, and slightly decreased in home W10 (3.0%).

TABLE 25

MEAN PARTICULATE EMISSION RATES BY WOODHEAT TECHNOLOGY

Technology	Model	Mean Emission Rate (g/hr)	σ[a]	N[b]
Conventional Technology Woodstoves	RSF "65"	23.8	9.1	20
	STSD[c]	18.0	7.5	16
	Sears "Automatic"	31.9	5.6	6
	Blaze King "King"	22.8	9.3	6
	Energy King "Princess"	17.9	1.9	3
	PES "Super 27" (uncertified)	18.7	6.3	10
Double Wall Flue Pipe	Security	32.8	5.7	5
	James A. Ryder	22.9	3.6	5
Low Emission Non-Catalytic Woodstoves	Osburn "Imperial 2000"	14.3	5.4	10
Catalytic "Add-On" Retrofit Devices	Nu-Tec	20.0	8.9	6
	Uni-Com	13.0	5.0	7
Integral Catalytic Woodstoves	Blaze King "King"	15.5	6.6	9
	Burning Log "Turbo 10"	9.0	3.2	10

a. Standard deviation.

b. Number of data values used to calculate mean emission rates.

c. Step top, spin draft woodstoves; includes Fisher "Grandma Bear," Fisher "Papa Bear," Fisher "Mama Bear," and Acorn "Ranger."

TABLE 26

MEAN OVERALL EFFICIENCY BY WOODHEAT TECHNOLOGY

Technology	Model	Mean Overall Efficiency[a]	σ^b	N[c]
Conventional Technology Woodstoves	RSF "65"	46.4%	7.9	20
	STSD[d]	52.4%	6.0	16
	Sears "Automatic"	44.2%	4.0	6
	Blaze King "King"	53.2%	6.9	6
	Energy King "Princess"	55.9%	3.5	3
	PES "Super 27" (uncertified)	52.2%	4.3	10
Double Wall Flue Pipe	Security	46.8%	4.7	5
	James A. Ryder	47.3%	5.5	5
Low Emission Non-Catalytic Woodstoves	Osburn "Imperial 2000"	48.2%	5.6	10
Catalytic "Add-On" Retrofit Devices	Nu-Tec	53.8%	5.9	6
	Uni-Com	56.6%	4.9	7
Integral Catalytic Woodstoves	Blaze King "King"	58.3%	6.3	9
	Burning Log "Turbo 10"	53.8%	3.7	10

a. Overall efficiencies calculated using a modified version of the Condar method.

b. Standard deviation.

c. Number of values used to calculate mean overall efficiency.

d. Step top, spin draft woodstoves; includes Fisher "Grandma Bear," Fisher "Papa Bear," Fisher "Mama Bear," and Acorn "Ranger."

TABLE 27

MEAN WOOD USE BY WOODHEAT TECHNOLOGY

Technology	Model	Mean Wood Use (dry kg/HDD[a])	N[b]
Conventional Technology Woodstoves	RSF "65"	1.59	20
	STSD[c]	1.44	16
	Sears "Automatic"	1.87	6
	Blaze King "King"	1.55	6
	Energy King "Princess"	1.25	3
	PES "Super 27" (uncertified)	0.93	10
Double Wall Flue Pipe	Security	1.26	5
	James A. Ryder	1.43	5
Low Emission Non-Catalytic Woodstoves	Osburn "Imperial 2000"	1.03	10
Catalytic "Add-On" Retrofit Devices	Nu-Tec	1.32	6
	Uni-Com	1.27	7
Integral Catalytic Woodstoves	Blaze King "King"	1.88	9
	Burning Log "Turbo 10"	1.01	10

a. Dry kilogram of wood used per Heating Degree-Day (HDD).

b. Number of values used to calculate mean wood use.

c. Step top, spin draft woodstoves; includes Fisher "Grandma Bear," Fisher "Papa Bear," Fisher "Mama Bear," and Acorn "Ranger."

Study participants in home W01 reported that the Security system gave the RSF "65" conventional technology woodstove better draft characteristics; however, increased creosote deposition rates were observed. Participants in home W01 could not detect any change in stove performance with the James A. Ryder double wall pipe. Study participants in home W10 could not detect any change in stove performance with either of the double wall systems.

In both homes the Security flue pipe system increased the particulate emission rates relative to the emission rate observed with the original single wall flue pipe in place. The James A. Ryder double wall flue pipe decreased the emission rate in home W01, and did not significantly affect the observed particulate emission rate in home W10.

B. Osburn "Imperial 2000"

The "Imperial 2000" had a mean emission rate of 14.3 g/hr and a mean overall efficiency of 48.2% for the study.

The "Imperial 2000" emissions performance was significantly different in homes W04 and W09, with mean emission rates of 9.6 g/hr and 19.0 g/hr, respectively. The study participants in home W04 seemed generally pleased with the operation of the woodstove, while the study participants in home W09 were unsatisfied with the burn times between refuelings and heat output. The homeowners in home W04 did feel that burn times were too short—a maximum burn time of 4 hours was achieved at a heat output setting used on colder winter days. The study participants in home W04 also felt that the heat output capability of the woodstove was not sufficient for very cold winter days. In spite of these observations, the participants in home W04 felt that the "Imperial 2000" was a much better woodstove than the Sears "Automatic." Neither homeowner indicated any difficulties with the operational controls or mechanical characteristics of the "Imperial 2000."

Wood usage in home W04 was reduced by 36.8% from Stage 1 to Stage 2 but is partially influenced by the differences in firebox size from the Sears "Automatic" (0.0821 m^3 [2.90 ft^3]) and the Osburn "Imperial 2000" (0.0436 m^3 [1.54 ft^3]). For home W09 wood usage actually increased by 9.0% during Stage 2. This result parallels the observed increases in emission and decrease in overall efficiency observed in Stage 2.

The chimney systems were significantly different in each of the homes with the "Imperial 2000." Home W04 had a chimney system consisting of 1.4 m (4.6 ft) of 15 cm single wall pipe and 5.5 m (18.0 ft) of 15 cm (6 in) ID packed pipe, with two 90° elbows. The chimney system in home W09 consisted of 3.4 m (11.2 ft) of 20 cm (8 in) ID packed pipe; however, the lower 1.5 m (4.9 ft) of the chimney was replaced by 15 cm (6 in) single wall pipe between sampling periods 5 and 6. The chimney system in home W09 did not have any elbows. After the replacement of the lower portion of the chimney in home W09 the homeowner reported increased heat output from the stove, but it still did not satisfy the homeowner. It is hypothesized that the straight, short chimney with a larger diameter in home W09 probably contributed to higher emission rates by creating relatively poor draft conditions as compared to home W04. Poor draft conditions can contribute to reduced overall efficiency performance and increased emissions.

The "Imperial 2000" had a small amount of creosote deposition relative to other stoves in the study. Mean burn rates were significantly higher in home W04 than in home W09. The mean overall efficiency for the "Imperial 2000" was slightly lower than the mean overall efficiency observed for all conventional technology woodstoves in the study.

The Oregon weighted particulate emission rate observed on the certification test of the "Imperial 2000" was 5.5 g/hr.[9]

C. Nu-Tec Catalytic Retrofit

The Nu-Tec Catalytic Retrofit had a mean particulate emission rate of 16.2 g/hr and a mean overall efficiency of 53.8% for the study.

The Nu-Tec installation on a RSF"65" conventional technology woodstove in home W02 caused smoke spillage problems that resulted in the device being removed from the study after two sampling periods. The smoke spillage problem in home W02 resulted from the Nu-Tec causing an excessive flue restriction that could not handle the volume of combustion gases under full loading conditions. As described in Section VI, several attempts to mitigate the smoke spillage problems were not effective.

In home W12 the Nu-Tec installed on a Fisher "Papa Bear" reduced mean particulate emissions from 25.3 g/hr in Stage 1 to 16.3 g/hr in Stage 2. Smoke spillage problems were also observed in this home. The smoke spillage seemed to most commonly occur when fueling the stove. The most serious smoke spillage problems occurred when the homeowner tried to start a fire in a cold stove. In this situation, if an adequate draft was not established to warm the chimney, the smoke would exit from the Nu-Tec unit housing into the house.

A creosote deposition evaluation in home W02 for the Nu-Tec was unavailable due to the short time period that the device was in place.

In home W12 the emissions and burn rates were reduced and overall efficiency was increased; however, in the homeowner's opinion these benefits did not outweigh the potential safety hazards and nuisance problems associated with the smoke spillage.

The mean overall efficiency observed for the Nu-Tec was slightly higher than the mean overall efficiency observed for all conventional technology woodstoves.

The mean catalyst lightoff time percentage observed for the Nu-Tec was 35.4%. This percentage was slightly lower than the man catalyst lightoff time percentage of 41.1% observed for all catalytic retrofits.

The Nu-Tec did not demonstrate any relative decrease in wood usage in either homes W02 or

W12. In fact, a slight increase in wood usage was demonstrated in home W02 (4.5%) between Stage 1 and the two sampling periods the Nu-Tec was operational in Stage 2.

As part of a study conducted by OMNI for the Pacific Northwest and Alaska Regional Biomass Energy Program administered by the Bonneville Power Administration, the Nu-Tec was tested according to Oregon Department of Environmental Quality protocol for woodstove emission certification tests.[9] The Nu-Tec was mounted on a conventional technology woodstove with a firebox volume of 0.0676 m^3 (2.39 ft^3) manufactured by Scott Stove Works. The weighted particulate emission rate for this test was 10.6 g/hr.

D. Uni-Com Catalytic Damper

The Uni-Com Catalytic Damper had a mean particulate emission rate of 13.0 g/hr and a mean overall efficiency of 56.6% for the study.

The Uni-Com exhibited the potential for significant emissions reduction in both homes where the device was installed. In home W05 the mean particulate emission rate was reduced from 14.3 g/hr in Stage 1 to 10.2 g/hr in Stage 2. In home W08 the mean particulate emission rate was reduced from 28.5 g/hr in Stage 1 to 15.0 g/hr in Stage 2. In each home mean burn rate was reduced and mean overall efficiency was increased. However, the creosote deposition rate was increased in each home.

The mean overall efficiency observed for the Uni-Com was significantly higher than the mean overall efficiency observed for all conventional technology woodstoves in the study.

The mean catalyst lightoff time percentage for the Uni-Com was 45.0%, which was slightly higher than the mean catalyst lightoff time percentage of 41.1% recorded on all catalytic "add-on" retrofit devices.

Wood usage decrease in home W05 was 25.3% between Stage 1 and 2 and 9.6% for home W08. This difference is probably influenced by the higher mean catalyst light-off achieved in home W05 due to higher average flue gas temperatures being generated by the Acorn "Ranger".

Most of the homeowner's comments on the performance of the Uni-Com related to the smoke spillage problems associated with this device. Neither homeowner indicated any difficulties in the mechanical operation of the Uni-Com catalyst bypass system

As a part of the study noted above conducted by OMNI and administered by the Bonneville Power Administration, the Uni-Com was mounted on the Scott Stove Works conventional technology woodstove and tested according to the Oregon Department of Environmental Quality protocol for woodstove emission certification tests.[10] The weighted particulate emission rate for this test was 3.4 g/hr. This emission value is a result of very controlled fuel loading, burn cycle, and sampling procedures, and is not intended to simulate in-situ residential emission performance.

In an in-situ study conducted by OMNI in Portland, Oregon, for the State of Oregon, Department of Environmental Quality, the Uni-Com was mounted on an Earth Stove "Model 101" conventional technology woodstove with a firebox volume of 0.1480 m^3 (5.23 ft^3). The Uni-Com was monitored for four one-week sampling periods. In this test the mean particulate emission rate observed for the Uni-Com was 17.4 g/hr.[11] The Uni-Com used in the Portland study also exhibited smoke spillage problems that were similar to those observed in Whitehorse. During three of the four sampling periods in the Portland study a ceramic disk which acts as a heat sink was removed from the Uni-Com. This action significantly reduced smoke spillage problems. The ceramic disk remained in place in the Uni-Com devices in both Whitehorse homes.

E. Blaze King "King"

The "King" had a mean emission rate of 15.5 g/hr and a mean overall efficiency of 58.3% for the study.

The mean particulate emission rates observed for the two homes with the "King" were virtually identical: 15.3 g/hr in home W07 and 15.6 g/hr in home W11. The range of emission rates observed was 7.4 g/hr to 25.4 g/hr in home W07, and 11.3 g/hr to 22.0 g/hr in home W11. A sampling equipment malfunction occurred in home W07 during sampling period 7 which resulted in the loss of the emission rate data.

The mean catalyst lightoff time percentage for the "King" was 73.0%, which was higher than the mean catalyst lightoff time percentage of 70.8% recorded for all integral catalytic woodstoves. The homeowners did not indicate any problems with achieving catalyst lightoff.

Wood use decreased by 17.5% in home W07 between Stages 1 and 2 and 5.9% in home W11. However, the mean wood use for both homes in Stage 2, 1.88 kg/HDD, is the highest of all new woodheat technologies. This average reflects the size of the Blaze King "King" firebox relative to other woodstoves evaluated in this study.

Home W07 showed an increase in particulate emission rates in each consecutive sampling period, as follows:

Sampling Period	Emission Rate (g/hr)	Burn Rate (kg/hr)
5	7.4	1.72
6	7.5	1.62
8	21.0	1.85
9	25.4	1.48

Home W11 did not exhibit a similar increase in consecutive sampling periods, but rather consistently elevated emission rates. An inspection of the stoves in homes W07 and W11 and subsequent laboratory testing of the catalytic combustors revealed the following problems:

- premature failure of catalyst performance (homes W07 and W11)
- gaps in gaskets around catalysts (W07 and W11)

- unseated or "tipped" catalyst (W11)
- misplaced catalyst access door (W11)
- warped combustor seat (W11)

Each of the above factors appeared to have significantly contributed to the measured elevated emission rates.

Other problems identified in both homes were improperly set thermostats, bypass door weld gaps and loose bypass door gaskets. It is believed that the improper setting of the bimetallic coil in the thermostat may be a contributing factor to the premature failure of catalyst performance. However, this hypothesis would have to be verified by laboratory simulation tests. While the loose bypass door gaskets and weld gaps did not appear to contribute to the observed elevated emissions, they do represent a potential emission control system problem, particularly if the gasket does not make contact with the bypass door edges over time. It should be noted that the manufacturer of the Blaze King "King" stoves has started to take corrective actions to minimize or eliminate the above identified problems.

Despite the identified problems, both homes were very pleased with the performance of the "King". In both homes the mean burn rate was decreased as compared to their conventional technology woodstoves, and heat output and burn times were sufficient to satisfy the homeowners.

Each homeowner also noted that it was difficulat to establish an initial draft when lighting a cold stove. Home W07 noted that using a larger than normal amount of newspaper and kindling helped to warm the chimney and establish the initial draft. Home W11 reported some smoke spillage when fueling the stove. This may be due to the home's 18 cm (7 in) diameter chimney system (home W07 had a 20 cm [8 in] diameter chimney system, as recommended by the manufacturer). It should be noted that the Canadian National Building Code allows a variation up to two (2) inches (either increase or decrease) from the flue pipe diameter recommended by the woodstove manufacturer.

Neither homeowner reported any significant operational difficulties or perceived any design problems with the "King". The mean overall efficiency for the "King" was the highest mean overall efficiency observed for woodstoves in the study. The creosote deposition rate was significantly reduced in home W07 between Stages 1 and 2 but did not appear to change in home W11.

The Oregon weighted particulate emission rate for the certification test of the "King" is 1.6 g/hr.[9]

F. Burning Log "Turbo 10"

The "Turbo 10" had a mean emission rate of 9.0 g/hr, which was the lowest measured mean particulate emission rate observed for all woodstove models in the study. The mean overall efficiency was 53.8%

The mean emission rates were 9.2 g/hr in home W03, and 8.8 g/hr in home W14. The two "Turbo 10" stoves demonstrated consistent relatively low emission performance under the relatively severe heat demand conditions found in Whitehorse. An inspection of the catalyst in home W03 revealed a 1.0 cm × 7.0 cm (0.39 in × 2.75 in) gap in the gasket material below the catalyst. Assuming the observed gap occurred during the stage 2 sampling period, it did not appear to have any significant effect on the emission performance of the stove. This may be indicative of an emission control system that is "forgiving" when a partial failure of a gasket occurs. Further laboratory tests would have to verify this qualitative observation.

The mean catalyst lightoff time percentage for the "Turbo 10" was 68.8%. Homes W03 and W14 had mean catalyst lightoff time percentages of 69.5% and 68.1%, respectively. This narrow range is either a statistical artifact due to the small data set for this study, or an indication that the "Turbo 10" design promotes consistent catalyst lightoff time percentages.

Both homes were pleased with the heat output of the woodstove. The study participants in home W03 commented that the convective nature of the heat from the "Turbo 10" was more comfortable than the radiant heat from their conventional stove. Wood use decreased 23.4% between Stage 1 and Stage 2 in home W03, and by 12.8% in home W14. The "Turbo 10" had the lowest average wood use, 1.01 kg (dry)/HDD, of any of the new woodheat technologies evaluated.

The study participants in home W14 were not satisfied with the amount of burn time between refuelings of the "Turbo 10." An eight-hour burn was not sufficient, so the homeowner replaced the "Turbo 10" with their RSF "65" at the conclusion of the study.

In both of the study homes mean burn rates were reduced as compared to the conventional technology woodstoves. The mean overall efficiency for the "Turbo 10" was higher than the mean overall efficiency observed for conventional technology woodstoves in the study. Creosote deposition rate was significantly reduced in both homes that used the "Turbo 10" (refer to Table 19).

Neither home noted any major operational problems with the "Turbo 10." Home W14 reported that creosote would deposit on the glass door at a low burn setting, but would burn off under a medium to high burn rate setting.

The Oregon weighted particulate emission rate for the certification test of the "Turbo 10" was 3.1 g/hr.[8]

G. Comparison By Woodheat Technology—Summary

Table 28 lists a summary of the particulate emission rates by woodheat technology classification in grams per hour, grams per kilogram, and grams per million Joule.

H. Fuel Type Comparison

In order to compare particulate emission data in a large data set that would be relatively insensitive to woodheat technology changes and changes in woodstove operating procedures by the study participants in individual sampling periods, overall mean gram per hour emission rates were

TABLE 28

PERFORMANCE SUMMARY BY WOODHEAT TECHNOLOGY

Technology	MEAN EMISSION RATES g/hr	g/kg	g/10⁶J	MEAN OVERALL EFFICIENCY (%)[a]	N[b]
Conventional Technology Woodstoves	21.8	16.3	1.7	49.8%	61
Vented Double Wall Flue Pipe	32.8	25.4	2.8	46.8%	5
Sealed Double Wall Flue Pipe	22.9	17.1	1.9	47.3%	5
Low Emission Non-Catalytic Woodstoves	14.3	14.2	1.6	46.2%	10
Catalytic "Add-On" Retrofit Devices	16.2	11.7	1.1	55.3%	13
Integral Catalytic Woodstoves	12.1	9.1	0.8	55.9%	19

a. Mean overall efficiency calculated using a modified version of the Condar method[7].

b. Number of data values used to calculate mean emission rates and mean overall efficiencies.

calculated for the "firekilled" and "seasoned" fuel types. The following summarizes the particulate emission rate mean, standard deviation, and number of data points for each fuel type:

Fuel Type	Mean Emission Rate (g/hr)	Standard Deviation	Number of Values
"Firekilled"	19.5	10.2	64
"Seasoned"	19.3	7.2	49

A student "t" statistical test on the above data set indicated that the probability is greater than 90% that the emission rates for the two fuel types are alike.

The homeowners indicated that the heat output from the "seasoned" fuel was less than the heat output observed when burning the "firekilled" fuel. The "seasoned" fuel had a higher average moisture content than the "firekilled," so the loss of latent heat by vaporization of the water in the fuel represents a loss in heat output. The average fuel moisture contents of the "firekilled" and "seasoned" fuels were 16.6% (dry basis) (σ = 2.5 and N = 93) and 29.4% (dry basis) (σ = 8.3 and N = 50), respectively. The homeowners preferred using "firekilled" fuel primarily because the lower moisture content helped when starting a fire in a woodstove. The "firekilled" wood is approximately 30 years old and has the same energy content on a dry basis as the "seasoned" wood. It appears that pole lengths of wood should be cut into "firebox" lengths and split if they are to "season" within a year under Whitehorse weather conditions.

Some homeowners also felt that the "seasoned" fuel produced more creosote. The creosote collection procedures did not allow this homeowner perception to be evaluated.

I. Creosote Analysis

The creosote sample collection program in Stage 1 had a number of problems related to sample identification and sample loss. In addition, there are inherent problems with accurate characterization of creosote deposition rates under in-situ conditions due to the complexities of creosote deposition and removal mechanisms. Therefore, caution should be used in the interpretation of the data related to creosote deposition rates related to specific woodheat technologies.

The dynamics of creosote deposition and removal by pyrolysis is influenced by several factors. The quantity of condensable material in the flue gas stream probably has the largest effect on creosote deposition. Other factors include chimney system length, size, and geometry; flue gas temperature and velocity; and flow restrictions in the chimney. The removal of creosote by pyrolysis is a very difficult factor to evaluate given the variation in burn rates between creosote collection periods. The creosote deposition rate trends observed in the study include:

- The double wall flue pipe system did not appear to change creosote deposition rates in home W01. The creosote deposition rate appears to be significantly reduced in home W10; however, a missing sample in Stage 2 makes this data highly questionable. No observation can be made between the Security and Ryder regarding creosote deposition rates due to the creosote collection methods.

- The Pacific Energy Systems "Super 27" (uncertified version) had an increased creosote deposition rate when compared with the Stage 1 woodstoves in both of the study homes.
- The Osburn "Imperial 2000" had a decreased creosote deposition rate when compared with conventional technology woodstoves in both of the study homes.
- In each of the four study homes with the catalytic "add-on" retrofit devices installed, the creosote deposition rate increased between 8.2% and 40.0%. However, the uncertainty associated with the creosote sample collection procedure indicates that the reported increases may be questionable. If this observation can be verified in laboratory tests, it raises a safety issue associated with the operation of catalytic "add-on" devices.
- In three of the four homes with integral catalytic woodstoves, creosote deposition rates as compared with the conventional technology woodstoves appeared to be significantly decreased. In the fourth home the creosote deposition rate appeared to be the same as the creosote deposition rate observed with the conventional technology woodstove.

K. Alternative Heat Use

There was no recorded measurement of alternative (backup) heat use in seven homes during the Stage 1 and 2 emission sampling period. The other seven homes had used alternative heat on the average of 3.2 hours per sampling week. The only consistent trend observed was a slight to moderate increase in alternative heat use during the coldest sampling periods. These observations support that woodstoves used in the study homes were the primary heat source.

L. Wood Usage

With the exception of two homes with the Nu-Tec "add-on" device and the one home with the "Imperial 2000" that had relatively high emissions, all other homes showed a decrease in wood use after new woodheat technologies were installed in the Stage 2 sampling period. The Uni-Com catalytic "add-on" damper showed an average reduction in wood usage (dry kg/HDD) of 17.4%, whereas the integral catalytic and the low-emission non-catalytic woodstoves showed average reductions of 14.9% and 13.9%, respectively. Caution must be used in the interpretation of changes in wood use between Stage 1 and Stage 2 since a number of factors, e.g., woodstove firebox size, overall efficiency, and operator fueling practices, influence wood use figures.

IX. CONCLUSIONS

The climate in Whitehorse is well suited to evaluate in-situ woodstove use under high burn rates and long periods of woodstove operation. The heating season in the Whitehorse area can be up to nine months long under sub-arctic conditions, so most woodstoves are subject to very heavy use much of the time. This study observed several sampling periods during which the stoves were operational 100% of possible total operational time. In many other sampling periods the stoves were operational over 90% of the time. The high amount of woodstove usage in this study allowed several new woodheat technologies to be evaluated under high heat demand conditions.

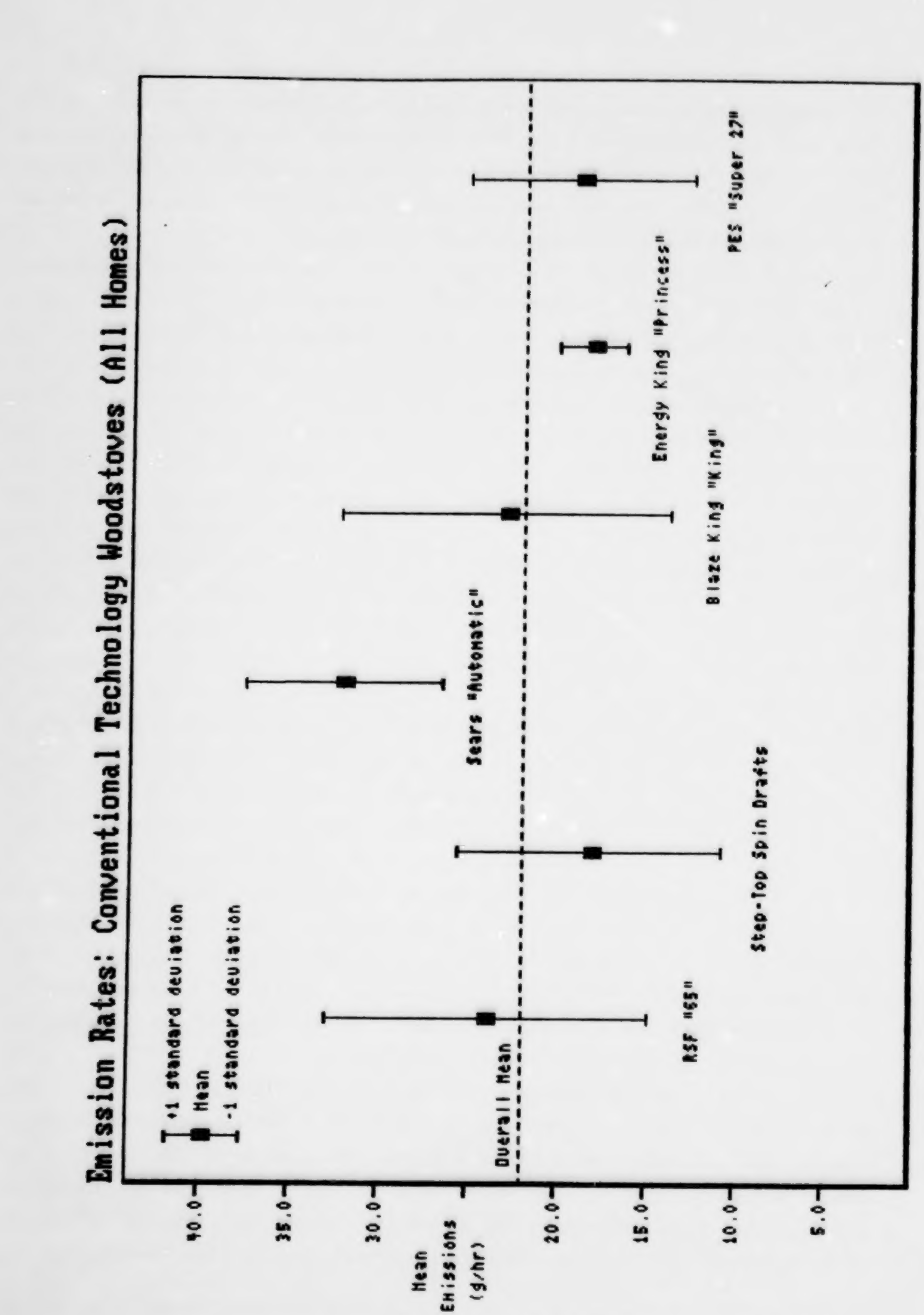
Figures 8 through 12 illustrate the mean gram per hour particulate emission rates with associated standard deviations observed for the individual woodheat technologies evaluated in the study. Figures 13 through 15 present mean particulate emission rates and associated standard deviations in grams per hour, grams per kilogram, and grams per million Joule by classification of woodheat technology.

The conventional technology woodstoves evaluated in the study had a mean particulate emission rate of 21.8 g/hr, which is considered at the low end of the range (typically 20 to 60 g/hr) for conventional technology woodstoves. Certain conventional technology woodstoves had very low emission rates, so it appears that primarily stove design and possibly operation of the appliance can significantly affect emissions rates. This was indicated by the individual conventional technology woodstove mean particulate emission rate range of 9.4 g/hr to 35.3 g/hr. The design of the stove will determine a general range of emission rate capabilities. Proper installation and good operating practices (e.g., using dry wood, not dampering down air intake, not overfilling the firebox) will increase the probability of achieving the lowest possible emission rates.

The largest data set collected for a conventional technology woodstove was for the RSF "65," which had mean particulate emission rates for individual homes ranging from 16.8 g/hr to 35.3 g/hr. An evaluation of factors, e.g. burn rates, average fuel loads, chimney system configuration, etc., that could influence emission performance did not indicate any significant factor contributing to the variation in mean emission rates between homes. Possibly, a detailed inspection of the RSF "65" stove would provide information that could explain the observed variability in emission performance.

The Security double wall flue pipe system with the ventilated airspace increased emission rates in both study homes. The probable cause for the measured increase in emission rates was due to the more rapid condensation of flue gases in the vicinity of the sampling probe. The James A. Ryder double wall flue pipe system with the sealed airspace decreased emission rates in one study home and did not change emission rates in the second study home. The homeowners with the double wall flue pipe could not detect any significant improvements in stove performance.

The two new technology non-catalytic woodstoves (Osburn "Imperial 2000") had a mean particulate emission rate of 14.3 g/hr, which was 34.4% lower than the conventional technology woodstove mean particulate emission rate of 21.8 g/hr. The mean overall efficiency of the low emission non-catalytic woodstoves was 48.2%, which was slightly lower than the conventional technology mean overall efficiency. The homeowners with the new technology non-catalytic woodstoves indicated that burn duration times under high heat demand conditions were too short, i.e.,



Emission Rates: Conventional Technology Woodstoves (All Homes)
+1 standard deviation
Mean
-1 standard deviation
Overall Mean
Mean
Emissions
(g/hr)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
RSF "65"
Step-Top Spin Drafts
Sears "Automatic"
Blaze King "King"
Energy King "Princess"
PES "Super 27"

FIGURE 8

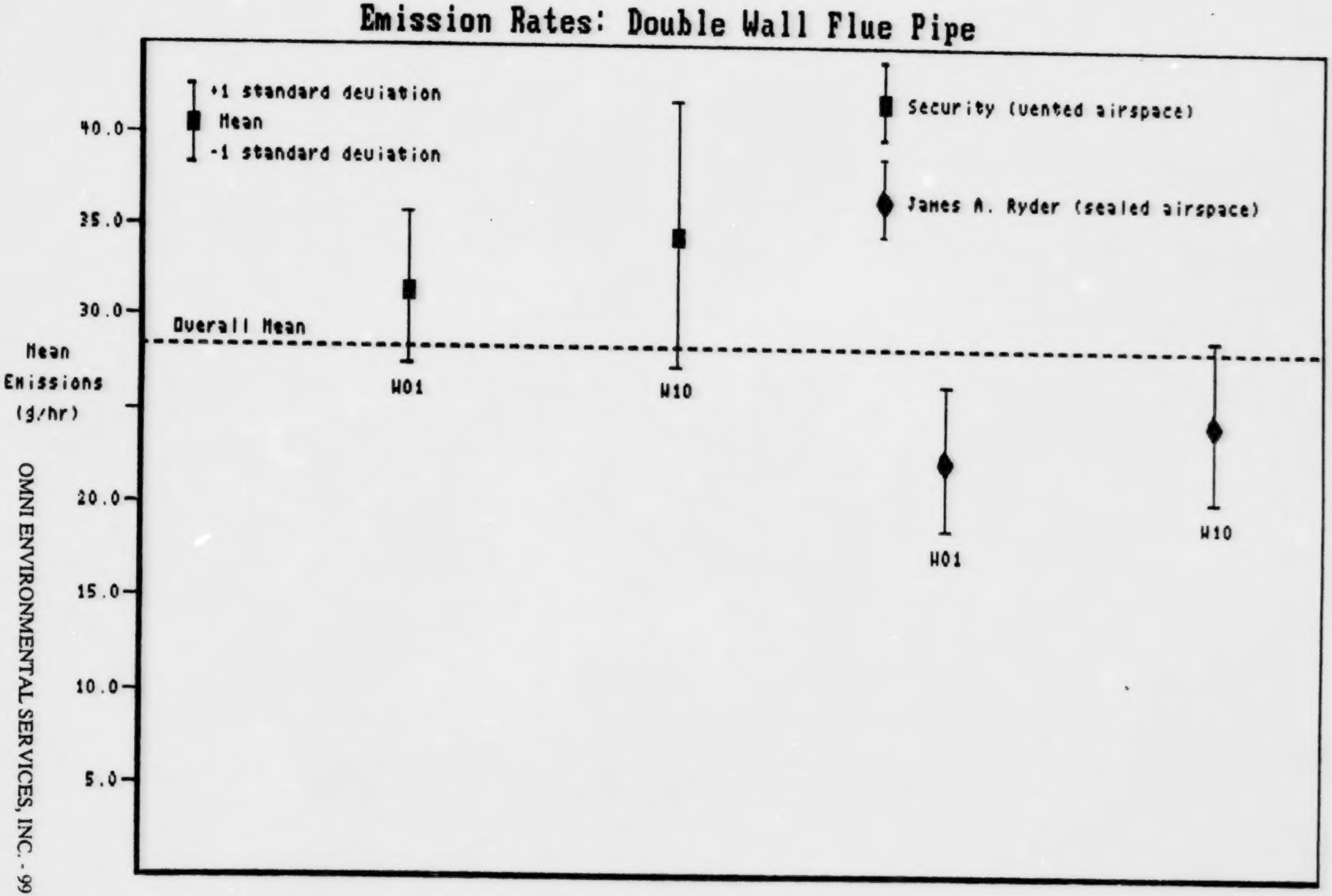

Emission Rates: Double Wall Flue Pipe
+1 standard deviation
Mean
-1 standard deviation
Security (vented airspace)
James A. Ryder (sealed airspace)
Overall Mean
Mean
Emissions
(g/hr)
40.0
35.0
30.0
20.0
15.0
10.0
5.0
W01
W10
W01
W10

FIGURE 9

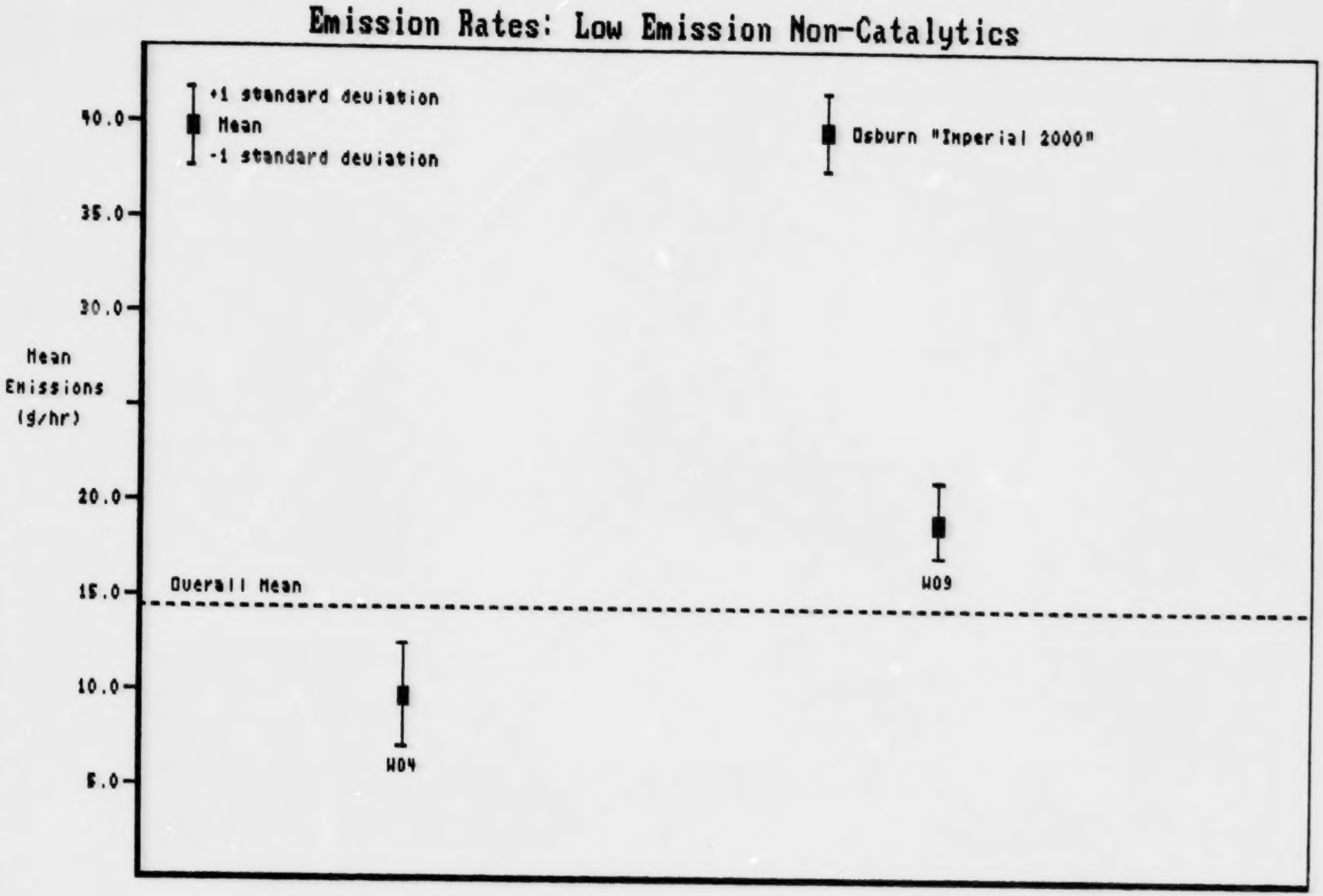

Emission Rates: Low Emission Non-Catalytics
+1 standard deviation
Mean
-1 standard deviation
Osburn "Imperial 2000"
Mean Emissions (g/hr)
40.0
35.0
30.0
20.0
15.0
10.0
5.0
Overall Mean
W04
W09

FIGURE 10

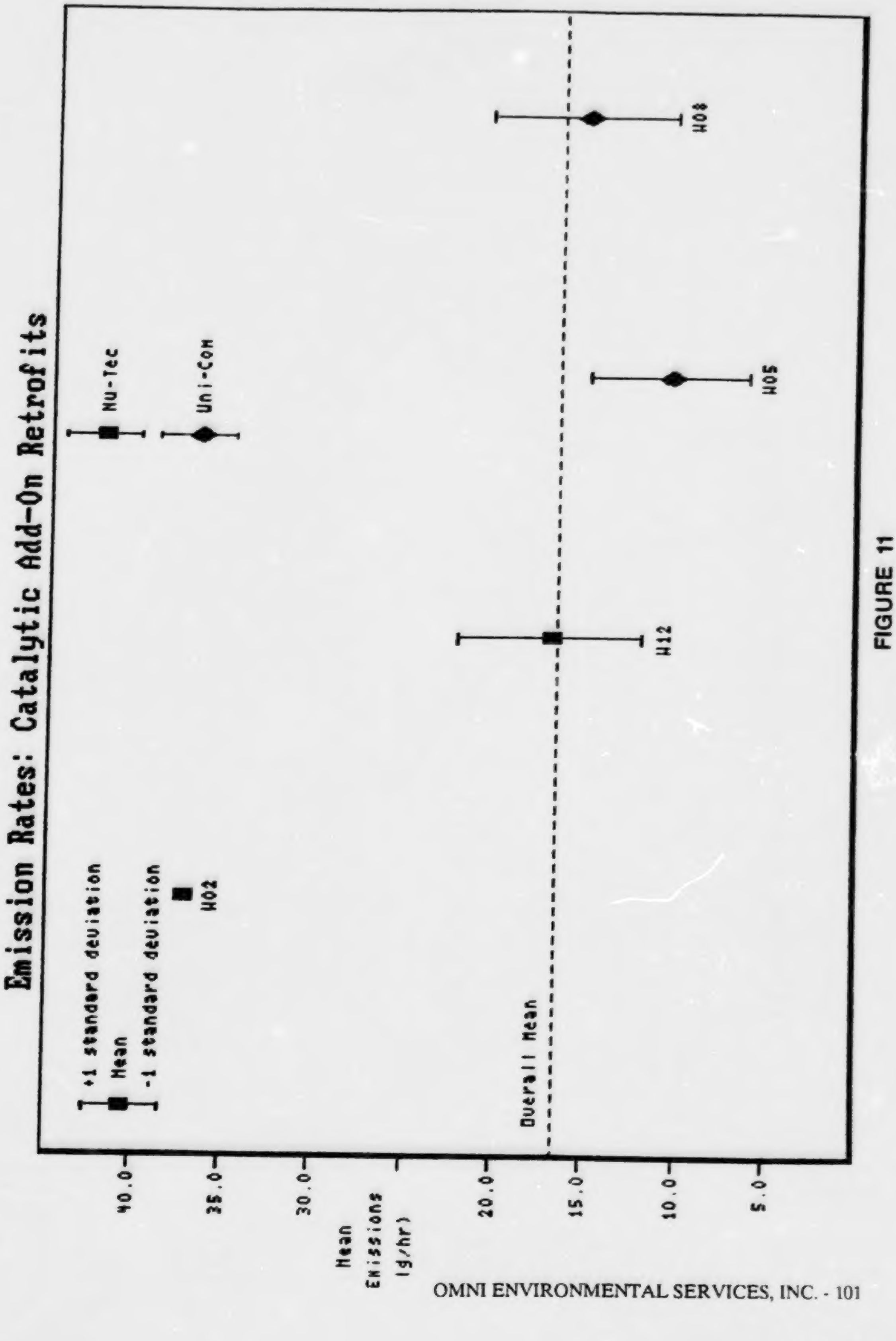
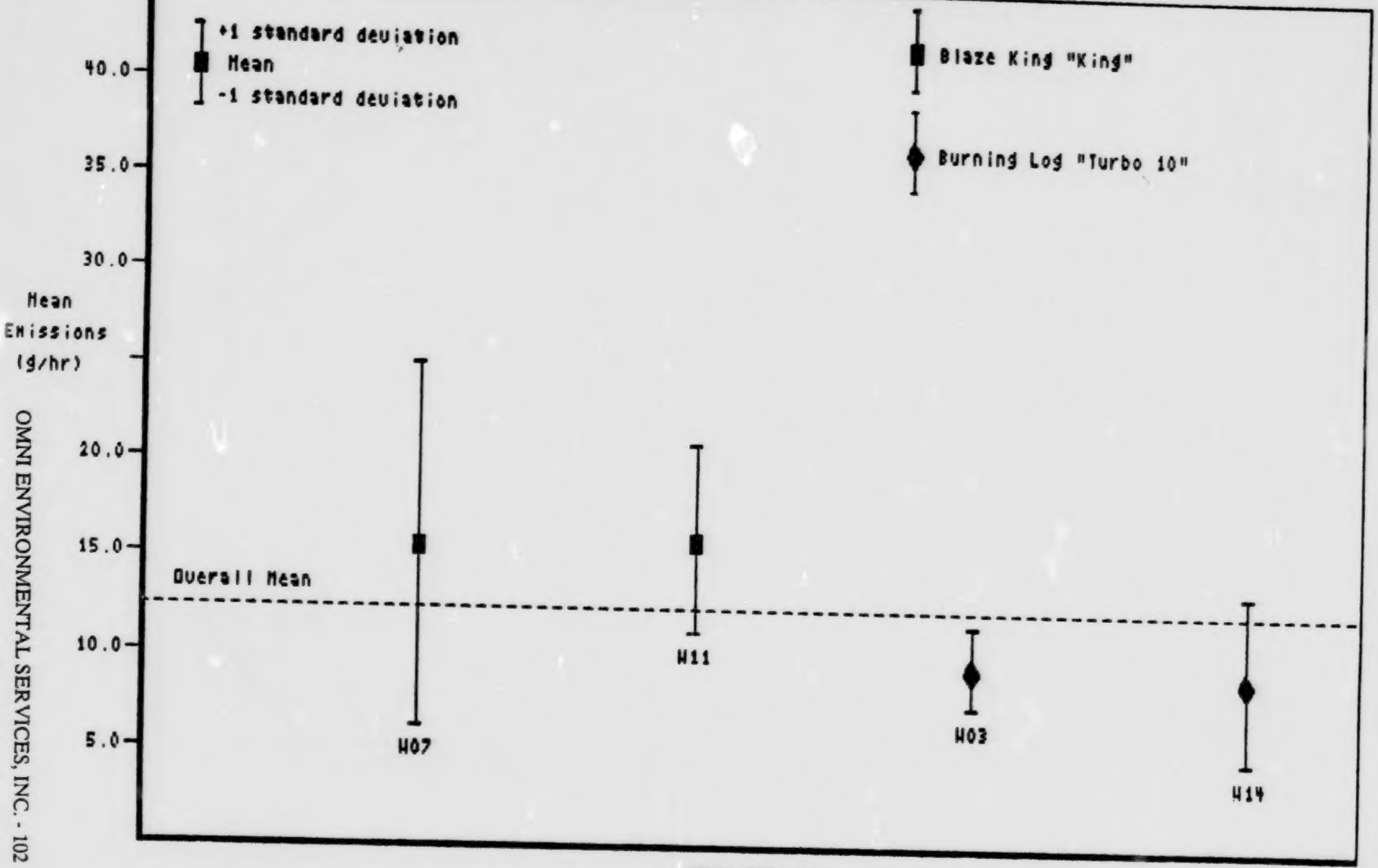

Emission Rates: Catalytic Add-On Retrofits
+1 standard deviation
Mean
-1 standard deviation
H02
Nu-Tec
Uni-Con
Overall Mean
H12
H05
H08
40.0
35.0
30.0
20.0
15.0
10.0
5.0
Mean
Emissions
(g/hr)

FIGURE 11



Emission Rates: Integral Catalytic Woodstoves

FIGURE 12

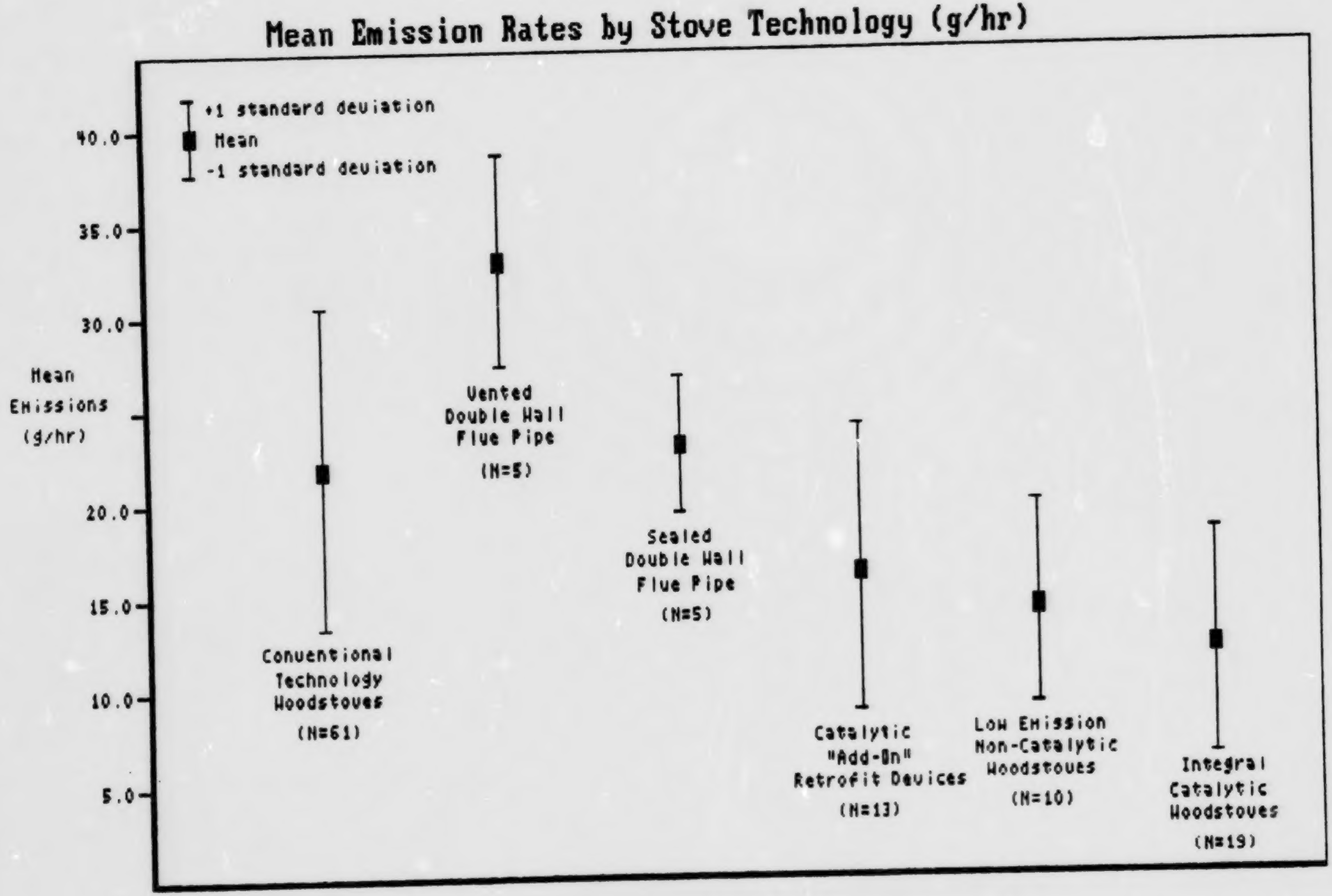

Mean Emission Rates by Stove Technology (g/hr)
+1 standard deviation
Mean
-1 standard deviation
Mean Emissions (g/hr)
40.0
35.0
30.0
20.0
15.0
10.0
5.0
Conventional Technology Woodstoves (N=61)
Vented Double Wall Flue Pipe (N=5)
Sealed Double Wall Flue Pipe (N=5)
Catalytic "Add-On" Retrofit Devices (N=13)
Low Emission Non-Catalytic Woodstoves (N=10)
Integral Catalytic Woodstoves (N=19)

FIGURE 13

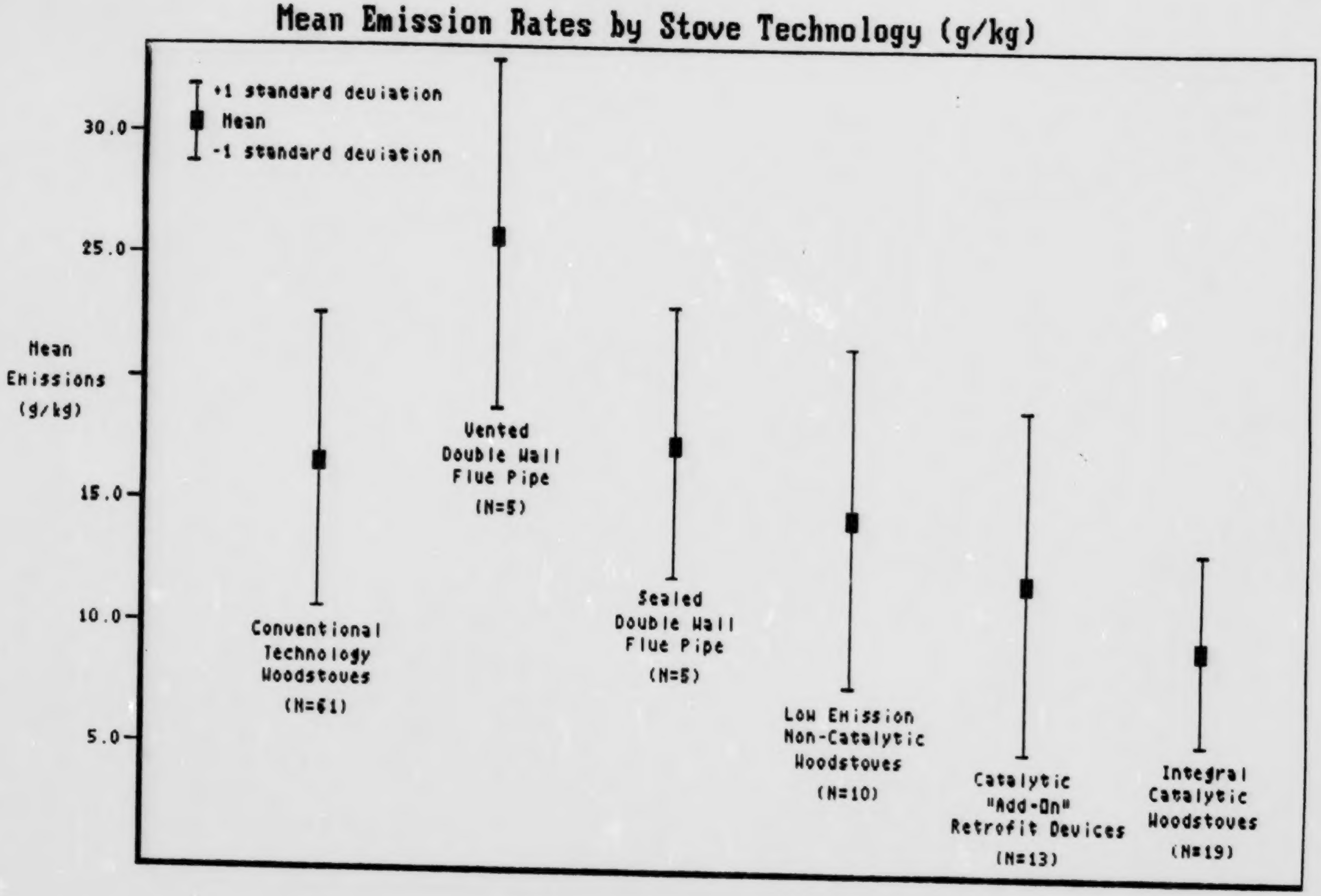

Mean Emission Rates by Stove Technology (g/kg)

FIGURE 14

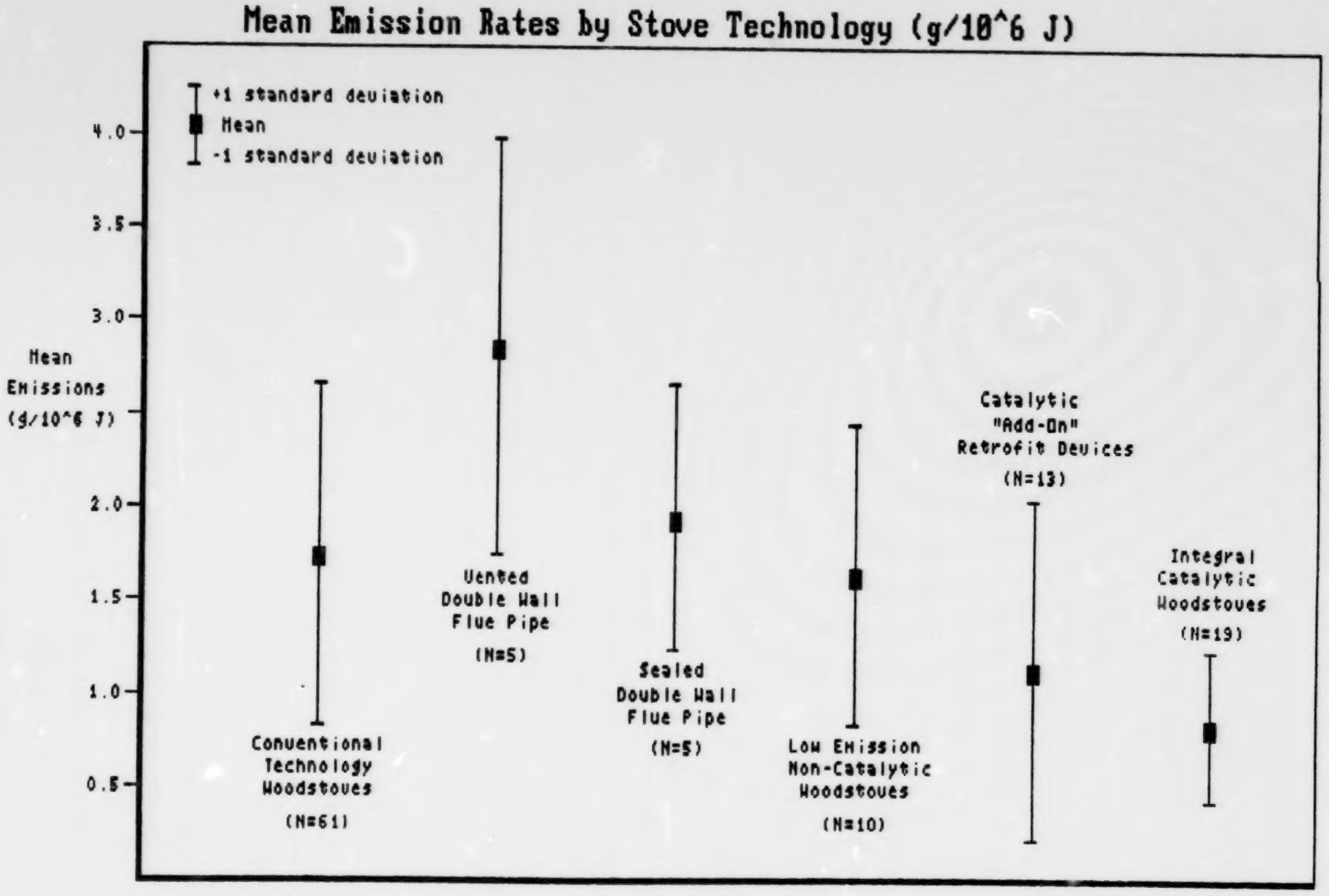

Mean Emission Rates by Stove Technology (g/10^6 J)
+1 standard deviation
Mean
-1 standard deviation
Mean
Emissions
(g/10^6 J)
4.0
3.5
3.0
2.0
1.5
1.0
0.5
Conventional
Technology
Woodstoves
(N=61)
Vented
Double Wall
Flue Pipe
(N=5)
Sealed
Double Wall
Flue Pipe
(N=5)
Low Emission
Non-Catalytic
Woodstoves
(N=10)
Catalytic
"Add-On"
Retrofit Devices
(N=13)
Integral
Catalytic
Woodstoves
(N=19)

FIGURE 15

approximately 3 to 5 hours. Since the low emission non-catalytic woodstoves evaluated in this study had relatively small fireboxes, frequent refueling was necessary to maintain high heat output. This frequent refueling pattern is common to Oregon certified non-catalytic stoves used in colder climates. The shorter burn times required the homeowners to occasionally refuel the stoves during the night. In the Whitehorse climate where the mean temperature is -19.4°C (-3°F) during the winter, the low emission non-catalytic stoves may be inconvenient to operate in standard sized homes. In a smaller, well-insulated home or apartment the heat from a new technology non-catalytic woodstove may be adequate for heating demand needs.

An important factor to consider in the installation of the new technology non-catalytic woodstoves is the chimney system. The study home that expressed the most satisfaction with the heat output of the new technology non-catalytics had a chimney system that met installation recommendations of the stove manufacturer. The study home that expressed the most dissatisfaction with the new technology non-catalytics had a chimney system that may not have provided adequate draft to optimize stove performance. While the data from this study is far from conclusive, it does indicate that a chimney system that is matched to the stove and has a reasonable length to promote good draft conditions is important in optimizing the performance of the new technology non-catalytic woodstoves.

The catalytic "add-on" retrofit devices that were installed on conventional technology woodstoves had a mean particulate emission rate 16.2 g/hr, which was 26% lower than the mean emission rate observed for the conventional technology woodstoves. The catalytic retrofits also significantly increased the overall efficiency of the conventional technology woodstoves on which the devices were installed. The mean overall efficiency for the catalytic retrofits was 55.3%, which was significantly higher than the mean overall efficiency for the conventional technology woodstoves. This technology classification has the potential for reducing particulate emissions from conventional technology woodstoves. However, the observed smoke spillage associated with these devices is a potential safety hazard. Further design improvements in these devices may overcome the problem observed in this study.

The mean catalyst lightoff time percentage for the catalytic retrofit devices was significantly lower than the mean catalyst lightoff time percentage for the integral catalytic woodstoves. This is not an unexpected result since catalytic stoves are designed to maximize catalytic combustion conditions by providing an enriched fuel mixture, i.e., high in unburned hydrocarbons, with an adequate supply of combustion air. The design of the conventional technology stove on which the catalytic "add-on" retrofit device is installed is a primary factor which influences the overall performance of the catalytic retrofit. Conventional technology woodstoves that generate relatively high flue gas temperatures (e.g., simple "box" type) appear to be more successful in maintaining catalyst lightoff conditions than stoves which have relatively more heat transfer surface, e.g. the RSF "65".

The reactions of the homeowners that used the catalytic "add-on" retrofit devices ranged from complete dissatisfaction to indifference. No homeowner reported any noticeable improvement in stove heat output or perceived efficiency; although recorded data indicated improvement in each of these areas. In the homeowners' opinions, the smoke spillage and associated safety hazards generally outweighed any benefit from the catalytic retrofit devices.

The integral catalytic woodstoves had the lowest particulate emission rates and highest overall efficiencies of all of the Stage 2 woodheat technologies. The mean particulate emisson rate observed for the integral catalytic woodstoves was 12.1 g/hr, which was 44% lower than the conventional technology woodstove mean particulate emisison rate of 21.8 g/hr. The mean overall efficiency for the integral catalytic woodstoves was 55.9%, which was relatively 12% higher than the mean overall efficiency for the conventional technology woodstoves.

The mean catalyst lightoff time percentage for the integral catalytic woodstoves was 70.8%, which indicates that the study participants were frequently able to achieve and maintain catalyst lightoff conditions. Field observations indicated that it was easier for homeowners to achieve catalyst lightoff with the integral catalytic woodstoves in comparison to the catalytic "add-on" retrofit devices. However, consistent catalyst lightoff may not be a good indicator of the emission performance of catalytic stoves if there is a failure(s) in other parts of the emission control system, e.g. gaps in the catalyst gasket.

The homeowners who operated the integral catalytic woodstoves were generally pleased with the heat output, burn times, and mechanical design of the stoves. As a technology group, the integral catalytic woodstoves exhibited the best potential for particulate emission reductions without sacrificing safety or convenience. The emission control systems problems revealed in the inspection of the Blaze King "King" stove in August 1987 indicate a need for improvement in manufacturing quality assurance procedures and better education for installers of new technology stoves. It should be noted that the manufacturer of the Blaze King "King" stoves has already initiated corrective actions based on the findings of this study.

The "firekilled" and "seasoned" fuel used during the study did not show any statistically significant differences in emission rate performance. The "seasoned" fuel had a higher moisture content. Pole lengths of "seasoned" wood are difficult to dry and frequently are wet after 12 months of drying. Therefore, pole lengths should be cut into "firebox" lengths and split to reduce the moisture content. The homeowners commented that this fuel was less convenient to start fires with and did not seem to burn as cleanly. Occasionally a mixture of "seasoned" and "firekilled" fuel was used during sampling periods that had been designated for "seasoned" fuel only. The percentages of fuel types burned in this report are based on estimates provided by the study participants. When calculating the "seasoned" emission rates versus the "firekilled" emission rates, the individual particulate emission rates were included in the fuel type category that corresponded to the highest percentage of fuel type used during that sampling period.

The creosote deposition rate data results are to be used with caution given the inherent problems associated with the creosote collection procedure. The double wall flue pipe did not seem to affect creosote deposition rates as compared to conventional technology woodstoves. The one model of low emission non-catalytic woodstove used in this study, the Osburn "Imperial 2000," had relatively lower creosote deposition rates. The catalytic retrofits all appeared to slightly increase the creosote deposition rate; however, the increases in this category may be problematical due to creosote collection methods. The integral catalytic woodstoves generally appeared to decrease creosote deposition rates with the exception of one home where the observed creosote deposition rate appeared to be the same as with the conventional technology woodstove.

One unexpected event was to discover at the end of this study that Pacific Energy Systems "Super 27" stoves used in homes W06 and W13 were uncertified, i.e., not Oregon certified non-catalytic stoves. The dealer supplying the stoves was under the impression the "Super 27" stoves were certified even though they did not have an Oregon DEQ woodstove certification label. The safety listing label did imply that an Oregon certified version of the "Super 27" was available from the manufacturer. This situation indicates the need for both improved consumer and dealer education regarding the identification of emission certified stoves. This unexpected result also points out the need to perform a thorough inspection of each stove prior to a start of any in-field woodstove study. The Oregon Department of Environmental Quality is presently investigating its authority to ensure stoves sold outside of Oregon which have been certified under a specific model number meet certification specifications.[12]

The study offered an opportunity to evaluate the potential safety benefits and problems associated with the new woodheat technologies. All of the catalytic "add-on" retrofit devices evaluated in the study resulted in various degrees of smoke spillage, primarily during fuel loading events. This observation would indicate the potential for increased indoor ambient woodstove emissions. Many of the new technology woodstove models evaluated in this study indicated the potential for reducing creosote deposition. This observation would appear to be a safety benefit in that the potential for flue fires may be reduced during a heating season with the new technology woodstoves.

Although the observed particulate emission rates associated with the Stage 2 technology woodstoves were generally higher than the certification test particulate emission rates, the potential for significant particulate emission reductions has been demonstrated. Other recent in-situ woodstove studies, which are still under peer review, have also demonstrated a wide range of emission performance of certified stoves.[13,14] It is expected that upon completion of the peer reviews the Whitehorse Efficient Woodheat Demonstration report results will be compared against the studies conducted in the northeastern and northwestern parts of the United States. This type of comparison study should give further insights into significant factors influencing "real-world" woodstove performance.

X. RECOMMENDATIONS FOR FURTHER ACTION

This study has provided new insights into the desirable performance characteristics and limitations of several new woodheat technologies. The study has also raised some issues that suggest further evaluation. Specifically they are:

1. The matching of chimney systems to new woodheat technologies and the effect on overall woodstove performance. The potential influence of this factor was best illustrated with the differences in the emission performance of the low-emission non-catalytic woodstoves and the observed concentration of creosote deposits in the vented double wall flue pipe.
2. Emission control system durability in integral catalytic woodstoves. The emission control system of typical integral catalytic woodstoves requires the interaction of the mechanical bypass, catalyst, and primary, secondary and (sometimes) tertiary air draft systems. A study of the emission control system factors which result in consistently low emission performance under both laboratory and in-situ conditions is essential in determining the long-term benefits of this technology classification.
3. An analysis of design factors which can reduce smoke spillage in the catalytic "add-on" retrofit devices. Every home in this study equipped with the retrofit devices experienced some degree of smoke spillage. An evaluation of current designs and improved designs could indicate a device that will safely and reliably reduce particulate emissions from numerous conventional technology woodstove models.
4. A more detailed study of the operation and applicability of low-emission non-catalytic woodstoves in colder climates. This classification of woodstoves has the potential of reducing particulate emission rates; however, the chimney system, heating demand, willingness of the operator to refuel more frequently, and heat retention characteristics of the home where the device is installed all influence the overall effectiveness and acceptablilty of the low-emission non-catalytic woodstoves. The development of more specific criteria for installations of low-emission non-catalytic woodstoves in colder climates is suggested by this study.
5. Emission reduction potential of the sealed airspace double wall flue pipe. The total data set collected in this type of flue pipe consisted of five sampling periods. A larger data set would help to resolve the issue of particulate emission reduction poetential of this type of flue pipe.

6. Improved education programs for both consumers and dealers to ensure that new technology woodstoves are properly installed and maintained. Sponsorship of these programs should be both from the public, e.g. regulatory agencies, and the private sector, e.g. manufacturers of woodstoves and trade organizations.
7. The requirement for random periodic inspections of certified woodstoves at the place of manufacture in the event that a Canadian woodstove emission performance regulation is adopted. This requirement would ensure that manufacturers do not implement changes in design or materials without having the approval of the appropriate regulatory agency.

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2. Reger, M. A Search for Epidemiological Effects of Woodsmoke Pollution in Whitehorse. Environment Canada, Environmental Protection Service. 1986.

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12. Personal communication with Barbara Tombleson, Oregon Department of Environmental Quality, 10/7/87.

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APPENDIX A

EVALUATION OF WOOD MOISTURE CONTENT ON PARTICULATE EMISSION RATE AND OVERALL EFFICIENCY CALCULATIONS

DATE: May 12, 1987

TO: Vic Enns, EMR

FROM: Carl Simons, OMNI Environmental Services

SUBJECT: Evaluation of Wood Moisture Content on Particulate Emission and Overall Efficiency Calculations

1. Delmhorst Moisture Meter Versus Oven-Drying Method for Measurement of Fuel Moisture Content

During the Whitehorse study, OMNI used a Delmhorst Moisture Meter (Model RC-1C) to evaluate fuel moisture content of logs (both "Firekilled" and "seasoned") used in Stage 1 and 2 stoves. This instrument was selected because it has been recognized as the industry standard for this type of meter. According to the literature provided by the Delmhorst Instrument company, the expected Delmhorst instrument accuracy (absolute units) is as follows: 0.5 percent from 6 to 12 percent moisture content - dry basis; within 1 percent from 12 to 20 percent ; and 2 percent from 20 percent to fiber saturation point (25 to 30 percent dry basis).[1]

As part of our normal woodstove certification process, OMNI compares Delmhorst measurements against oven-dry samples (using ASTM 2016-74 procedure) for each certification test. According to OMNI laboratory personnel, over 95 percent of the Delmhorst and oven-dry moisture content values are within 3 percent (relative difference) of each other. Differences of greater than 3 percent (generally in the range of 5 to 10 percent) are due to wood containing a high percentage of knots. It is recognized that the Delmhorst as used in certification tests is used over a limited range of fuel moisture content values (19 to 25 percent dry basis).

Table 1 summarizes the Delmhorst corrected meter readings for the wood samples evaluated for moisture content in the Whitehorse study. This table indicates that 74 percent of the samples were measured with a fuel moisture content less than 25 percent (dry basis); 13 percent in the range of 25.1 to 30.0 percent (dry basis) and 13 percent of the samples in the range of 30.1 to 40.0 percent (dry basis).

Since receiving the initial CCRL Delmhorst versus oven-dry moisture content values,[2] OMNI has investigated the potential impact on calculated emission rates and overall efficiency values. Table 2 presents a compilation of data comparing Delmhorst measurements (corrected for pin type, ambient temperature and species) versus oven-dry values for wood samples collected in Whitehorse. The first ten samples are from the original data set from CCRL.

Logs A, B and C represent additional comparability moisture content data that was performed by OMNI staff in Whitehorse. Three one-inch "slices" were cut from each log to evaluate (1) the Delmhorst values as measured directly on typical logs versus oven-dried values; and (2) the variation in moisture content (based on oven-dried measurement technique) across the log.

Since Table 2 shows that the largest relative measured difference in fuel moisture content was 34.7 percent (Home W-08, seasoned source) the assumptions regarding the inaccuracy of the Delmhorst fuel moisture values in Table 4 appear to be conservative. Therefore, relatively accurate comparison of woodstove performance for both emissions and overall efficiency can be calculated even with large uncertainties with fuel moisture measurements.

References

1. Instruction Booklet for Delmhorst Moisture Meter (RC-1C), Delmhorst Instrument Company, Towaco, New Jersey.

2. Memo from Ron Braaten to Vic Enns dated March 25, 1987.

3. "Handbook for Measuring Woodstove Emissions and Efficiency Using the Condar Sampling System." S. G. Barnett, 1985.

4. "Standard Method for Measuring the Emissions and Efficiencies of Residential Woodstoves." Oregon Department of Environmental Quality, 1984.

Table 1

SUMMARY OF CORRECTED FUEL MOISTURE VALUES AS MEASURED WITH A DELMHORST MOISTURE METER

	Fuel Moisture Content (Percent Dry Basis)		
Home	<25%	25.0%-30.0%	30.1%-40.0%
W-01	7	1	1
W-02	5	4	0
W-03	6	2	1
W-04	9	0	0
W-05	6	3	0
W-06	6	1	2
W-07	9	0	0
W-08	6	2	1
W-09	7	0	2
W-10	7	0	2
W-11	5	0	4
W-12	7	2	0
W-13	7	-	2
W-14	7	1	1
Total Samples	94	16	16
Percent	74	13	13

Table 2

COMPARISON OF CORRECTED DELMHORST MOISTURE METER VERSUS OVEN-DRIED MEASUREMENTS FOR "FIREKILLED" AND "SEASONED" WOOD SAMPLES FROM WHITEHORSE

		Delmhurst Meter			
Home	Species	OMNI[1]	CCRL[2,3]	Oven-Dried	Absolute Difference[4]
W-14	Seasoned Spruce	27.0	26.7	31.5	-4.5 (-4.8)
W-15	Firekilled Lodgepole Pine	15.7	18.7	17.3	-1.6 (+1.4)
W-01	Green Lodgepole Pine	30.4	27.9	29.6	+0.8 (-1.7)
W-13	Seasoned Lodgepole Pine	29.6	27.3	33.2	-3.6 (-5.9)
W-08	Firekilled Lodgepole Pine	21.6	20.4	13.4	+8.2 (+7.0)
W-08	Seasoned Spruce	29.0	26.7	40.9	-11.9 (-14.2)
W-11	Firekilled Lodgepole Pine	15.1	13.6	13.8	+1.3 (-0.2)
W-10	Seasoned Spruce	22.8	17.1	18.6	+4.2 (-1.5)
W-12	Firekilled Lodgepole Pine	17.7	15.8	16.1	+1.6 (-0.3)
W-13	Firekilled Lodgepole Pine	23.1	21.0	21.1	+2.0 (-0.1)
Log A	Firekilled Lodgepole Pine	19.0	----	19.2 (slice 1)	-0.2
Log A	Firekilled Lodgepole Pine	19.0	----	19.2 (slice 2)	-0.2
Log A	Firekilled Lodgepole Pine	19.0	----	19.5 (slice 3)	-0.5
Log B	Seasoned Spruce	29.3	----	32.7 (slice 1)	-3.4
Log B	Seasoned Spruce	29.3	----	33.9 (slice 2)	-3.6
Log B	Seasoned Spruce	29.3	----	34.5 (slice 3)	-4.2
Log C	Seasoned Spruce	57.4	----	43.5 (slice 1)	+14.1
Log C	Seasoned Spruce	57.4	----	44.6 (slice 2)	+13.8
Log C	Seasoned Spruce	57.4	----	43.7 (slice 3)	+13.7

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1. The average of five measurements per log

2. As measured on coupon from log

3. Assumes Delmhorst measurement made at 23.9 degrees C (75 degrees F)

4. Absolute difference in moisture content percent between Delmhorst and oven-dried values. CCRL values in parentheses.

NOTE: All measurements are dry basis

Table 3

COMPARISON OF MODIFIED CONDAR METHOD CALCULATED OVERALL EFFICIENCY VERSUS OREGON STANDARD METHOD CALCULATED OVERALL EFFICIENCY

Woodstove Technology	Burn Rate (Dry kg/hr)	Modified Condar Overall Efficiency	Oregon Standard Overall Efficiency	Modified Condar Versus Oregon Standard-Relative Percent Difference
Internal Retrofit Catalytic	0.60	81.3%	76.9%	+5.7%
Internal Retrofit Catalytic	2.39	68.9%	60.8%	+13.3%
Low Emission New Technology	1.91	65.1%	65.8%	-1.5%
Low Emission New Technology	1.19	62.6%	68.5%	-8.6%
Integral Catalytic	1.43	77.0%	72.9%	+5.6%
Integral Catalytic	2.56	77.0%	73.1%	+5.3%
Conventional Technology	2.35	61.7%	59.4%	+3.9%
Conventional Technology	0.77	57.6%	58.0%	-0.7%

Modified Condar Versus Oregon Standard Mean Relative Percent Difference 5.6%

Table 4

ANALYSIS OF THE IMPACT OF CHANGING FUEL MOISTURE CONTENT ON BURN RATE, PARTICULATE EMISSIONS AND OVERALL EFFICIENCY CALCULATIONS

Home/Sample Code	Fuel Moisture (Dry Basis)	Burn Rate (kg-dry/hr)	Emission Factors			Overall Efficiency
			g/hr	g/kg	g/10^6J	
W03-3	29.2% *	1.42	14.9	10.5	0.9	53.0%
	40.0% (+33.1%)	1.31 (-7.7%)	13.7 (-8.0%)	10.5 (0)	1.0 (+11.1%)	52.1% (-1.9%)
	50.0% (+71.2%)	1.22 (-14.1%)	12.8 (-14.1%)	10.5 (0)	1.0 (+11.1%)	51.6% (-2.6%)
W04-3	21.1% *	2.13	39.3	18.4	2.2	41.8%
	30.0% (+42.1%)	1.98 (-7.0%)	36.6 (-6.8%)	18.4 (0)	2.2 (0)	41.1% (-1.7%)
	40.0% (+89.5%)	1.84 (-13.6%)	34.0 (-13.5%)	18.4 (0)	2.2 (0)	40.6% (-2.9%)
W09-3	24.0% *	0.88	10.9	12.4	0.9	64.5%
	30.0% (+25.0%)	0.84 (-4.5%)	10.4 (-4.6%)	12.4 (0)	0.9 (0)	64.1% (-0.6%)
	40.0% (+66.7%)	0.78 (-11.4%)	9.7 (-11.0%)	12.4 (0)	0.9 (0)	63.5% (-1.6%)
W12-3	20.0% *	1.49	25.2	16.9	1.5	53.9%
	30.0% (+50.0%)	1.38 (-7.4%)	23.2 (-7.9%)	16.9 (0)	1.5 (0)	53.2% (-1.3%)
	40.0% (+100.0%)	1.28 (-14.0%)	21.6 (-14.3%)	16.9 (0)	1.5 (0)	52.6% (-2.4%)

* As measured

Figures in parentheses are relative percent change as compared to calculated values based on field-measured moisture values

APPENDIX B

CALCULATION PROCEDURES

Calculation Procedures

1. **Mass particulate emissions/ mass dry wood burned**

$$= \frac{MP \times SV}{FR \times SD\ (1 - [\%O_2/20.9\%])}$$

2. **Mass particulate emissions/ heat output**

$$= \frac{MP \times SV}{FR \times SD \times HC \times EF\ (1 - [\%O_2/20.9\%])}$$

3. **Mass particulate emissions/ time**

$$= \frac{MP \times SV \times MDW}{FR \times SD \times SP\ (1 - [\%O_2/20.9\%])}$$

4. **Mass particles/ volume**

$$= \frac{MP}{FR \times SD}$$

where:

MP = mass particulate emission (g)
SV = stoichiometric volume (l/kg dry wood)
FR = sampling flow rate (l/minute)
SD = sampling duration (minutes)
O_2 = oxygen in flue gas (% by volume)
HC = heat content of wood (J/kg wood)
EF = efficiency factor (%/100)
MDW = mass dry wood (kg)
SP = sampling period (hours) - total period stove was in operation, with flue temperature > 39°C.

5. Stoichiometric Volumes

Stoichiometric volumes have been calculated by species from the carbon, hydrogen, oxygen, and nitrogen content of the wood. Table B-1 lists the carbon, hydrogen, oxygen, nitrogen values, and heat content used for each species. Entries in Table B-1 are from actual analyses of the wood fuel. The true stoichiometric volumes were modified for stove technology types due to the level of incomplete combustion (viz, the CO content of flue gas) characteristic of each technology type. Table B-2 gives the estimated flue gas CO and CO_2 concentrations characteristic of the different technology types. Table B-3 lists the specific modified stoichiometric volumes for the various used species and stove technology types used.

6. Efficiency Factor

Efficiency factors were determined using a modified version of the "Condar Technique" (Handbook for Measuring Woodstove Emissions and Efficiency Using the Condar Sampling System, S. G. Barnett, August 1, 1985). The "Condar" Method was adapted to the AWES system by using the AWES g/kg value. The efficiency factors are calculated from the emission factor (g/kg), the average flue gas oxygen content, the average stack temperature, and wood moisture. Attachment B-1 gives the procedures followed to calculate efficiency factors with this technique.

Table B-1

Elemental and Higher Heat Contents of Wood Fuel

Species	Elemental Content (%) C, H, O, N	Higher Heat Content (Joules x 10^6/ kg dry wood)
1. Lodgepole Pine	49.84, 6.13, 43.42, 0.22	19.81
2. White Spruce	50.36, 6.09, 42.59, 0.33	20.16

Table B-2

Estimated Flue Gas CO and CO_2 Content by Stove Technology Type

Stove Technology	Volume % CO	Volume % CO_2	$\frac{\text{Moles CO}}{\text{Moles CO + Moles CO}_2}$	$\frac{\text{Moles CO}_2}{\text{Moles CO + Moles CO}_2}$
Catalytic	0.2	10.0	0.03	0.97
Add-on/Retrofit	0.8	10.0	0.11	0.84
Low Emission	1.3	10.0	0.17	0.83
Conventional	2.0	10.0	0.24	0.76

Table B-3

Calculated Stoichiometric Volumes by Wood Species and Stove Technology Types

Species	Stoichiometric Volumes (liter/dry kg)			
	Catalytic	Add-on/Retrofit	Low Emission	Conventional
1. Lodgepole Pine	4856	4705	4592	4460
2. Seasoned Spruce	4919	4767	4653	4520

Attachment B-1

Making a Woodstove Efficiency Determination Using the Condar Emissions System

The overall efficiency of a woodstove is the product of combustion efficiency times heat transfer efficiency. These instructions will treat combustion efficiency first, then heat transfer efficiency and finally, overall efficiency. If you are interested in the scientific background of these procedures, write to Condar Company.

Combustion efficiency is easily determined by using the table below (for the basic equation and its derivation, write to Condar Company). Simply locate your Condar emission factor on the table and read the corresponding combustion efficiency. The data base for emission factors above 20 g/kg is limited, so corresponding combustion efficiencies must be considered approximate.

COMBUSTION EFFICIENCY USING CONDAR EMISSIONS FACTORS
(VALUES ABOVE 20 GM/KG ARE APPROXIMATE, HAVING BEEN
DERIVED FROM LIMITED OEQ AND TVA DATA)

CONDAR EMISSION FACTOR GM/KG	COMBST. EFFICIENCY (%)	CONDAR EMISSION FACTOR GM/KG	COMBST. EFFICIENCY (%)	CONDAR EMISSION FACTOR GM/KG	COMBST. EFFICIENCY (%)	CONDAR EMISSION FACTOR GM/KG	COMBST. EFFICIENCY (%)	CONDAR EMISSION FACTOR GM/KG	COMBST. EFFICIENCY (%)
0.1	98.66	5.1	87.21	10.1	80.69	15.1	75.40	20.5	70.42
0.2	98.16	5.2	87.06	10.2	80.58	15.2	75.30	21	69.99
0.3	97.68	5.3	86.91	10.3	80.46	15.3	75.20	21.5	69.56
0.4	97.24	5.4	86.76	10.4	80.35	15.4	75.11	22	69.14
0.5	96.91	5.5	86.61	10.5	80.23	15.5	75.01	22.5	68.72
0.6	96.48	5.6	86.47	10.6	80.12	15.6	74.91	23	68.30
0.7	96.13	5.7	86.32	10.7	80.01	15.7	74.81	23.5	67.89
0.8	95.81	5.8	86.18	10.8	79.90	15.8	74.72	24	67.48
0.9	95.50	5.9	86.03	10.9	79.78	15.9	74.62	24.5	67.07
1	95.21	6	85.89	11	79.67	16	74.53	25	66.67
1.1	94.92	6.1	85.75	11.1	79.56	16.1	74.43	25.5	66.27
1.2	94.65	6.2	85.61	11.2	79.45	16.2	74.33	26	65.87
1.3	94.38	6.3	85.47	11.3	79.34	16.3	74.24	26.5	65.48
1.4	94.11	6.4	85.33	11.4	79.23	16.4	74.14	27	65.09
1.5	93.88	6.5	85.19	11.5	79.13	16.5	74.05	27.5	64.70
1.6	93.64	6.6	85.06	11.6	79.02	16.6	73.95	28	64.31
1.7	93.40	6.7	84.92	11.7	78.91	16.7	73.86	28.5	63.93
1.8	93.17	6.8	84.79	11.8	78.80	16.8	73.77	29	63.55
1.9	92.94	6.9	84.65	11.9	78.69	16.9	73.67	29.5	63.17
2	92.72	7	84.52	12	78.59	17	73.58	30	62.80
2.1	92.50	7.1	84.39	12.1	78.48	17.1	73.48		
2.2	92.29	7.2	84.25	12.2	78.37	17.2	73.39		
2.3	92.08	7.3	84.12	12.3	78.26	17.3	73.30		
2.4	91.88	7.4	83.99	12.4	78.16	17.4	73.21		
2.5	91.67	7.5	83.86	12.5	78.05	17.5	73.11		
2.6	91.47	7.6	83.73	12.6	77.95	17.6	73.02		
2.7	91.28	7.7	83.60	12.7	77.85	17.7	72.93		
2.8	91.09	7.8	83.48	12.8	77.75	17.8	72.84		
2.9	90.90	7.9	83.35	12.9	77.63	17.9	72.74		
3	90.71	8	83.22	13	77.53	18	72.65		
3.1	90.52	8.1	83.10	13.1	77.43	18.1	72.56		
3.2	90.34	8.2	82.97	13.2	77.33	18.2	72.47		
3.3	90.16	8.3	82.85	13.3	77.23	18.3	72.38		
3.4	89.98	8.4	82.72	13.4	77.13	18.4	72.29		
3.5	89.80	8.5	82.60	13.5	77.03	18.5	72.20		
3.6	89.63	8.6	82.47	13.6	76.98	18.6	72.11		
3.7	89.46	8.7	82.35	13.7	76.89	18.7	72.02		
3.8	89.29	8.8	82.23	13.8	76.78	18.8	71.93		
3.9	89.12	8.9	82.11	13.9	76.68	18.9	71.84		
4	88.95	9	81.99	14	76.49	19	71.75		
4.1	88.78	9.1	81.87	14.1	76.39	19.1	71.66		
4.2	88.62	9.2	81.75	14.2	76.29	19.2	71.57		
4.3	88.46	9.3	81.63	14.3	76.19	19.3	71.48		
4.4	88.30	9.4	81.51	14.4	76.09	19.4	71.39		
4.5	88.14	9.5	81.39	14.5	75.99	19.5	71.30		
4.6	87.98	9.6	81.27	14.6	75.89	19.6	71.21		
4.7	87.83	9.7	81.16	14.7	75.79	19.7	71.13		
4.8	87.67	9.8	81.04	14.8	75.69	19.8	71.04		
4.9	87.52	9.9	80.92	14.9	75.60	19.9	70.95		
5	87.36	10	80.81	15	75.50	20	70.86		

Example: Condar emission factor = 5.0 gm/kg
Combustion efficiency from table = 87.4%

Use the table below do determine heat transfer efficiency. The values in the table are derived from typical hardwood containing 6.5% hydrogen, 50% carbon, 20% moisture. See the box below the table for an example.

AVERAGE STACK TEMPERATURE (°F)

AVERAGE OXYGEN PERCENT	150	200	750	300	350	400	450	500	550	600	650
4	87.8	86.5	85.2	83.9	82.6	81.3	80.1	78.7	77.5	76.1	74.9
5	87.7	86.3	85.0	83.6	82.3	80.9	79.6	78.2	76.9	75.5	74.1
6	87.5	86.1	84.7	83.3	81.9	80.3	79.0	77.5	76.2	74.7	73.2
7	87.4	85.9	84.4	82.9	81.4	79.8	78.4	76.8	75.3	73.7	72.2
8	87.2	85.6	84.0	82.4	80.8	79.1	77.6	75.9	74.3	72.6	71.0
9	87.0	85.3	83.6	81.8	80.1	78.3	76.6	74.8	73.2	71.3	69.6
10	86.8	84.9	83.1	81.2	79.3	77.3	75.6	73.6	71.8	69.9	68.0
11	86.6	84.5	82.5	80.4	78.4	76.3	74.3	72.2	70.2	68.1	66.1
12	86.2	84.0	81.7	79.5	77.2	74.9	72.7	70.6	68.2	65.9	63.6
13	85.8	83.3	80.8	78.3	75.8	73.1	70.7	68.1	65.7	63.1	60.6
14	85.3	82.4	79.6	76.7	73.9	71.0	68.2	65.3	62.5	59.6	56.7
15	84.6	81.3	78.0	74.7	71.4	68.0	64.8	61.5	58.3	54.9	51.6
16	83.5	79.6	75.7	71.8	67.8	63.8	60.0	56.0	52.2	48.1	44.2
17	82.0	77.1	72.3	67.4	62.5	57.5	52.8	47.8	43.2	38.1	33.2
18	79.4	73.0	66.5	60.0	53.5	46.9	40.5	33.9	27.6	20.9	14.5

*CORRECTION FACTORS

(1) For Douglas Fir subtract 0.5%

(2) Tables Values are for 20% (moist basis) wood moisture.

Correction For Wood Of Different Wood Moisture.

Stack Temp.	Heat Transfer Correction For Each 10% Difference In Wood Moisture
200	1.4%
300	1.4%
400	1.5%
500	1.5%
600	1.6%

Add the wood moisture correction to your heat transfer % if your wood is dryer than 20% moisture and subtract if your wood is wetter.

Example: From A Douglas Fir Test Your test results show:

Average Stack Temperature = 400°
Average Oxygen = 13%
Average Wood Moisture = 25%
Heat Transfer Value From Table = 73.1
Fir Correction = -0.5
Wood Moisture Correction = - .75
Your Heat Transfer % = 71.85

The values in the table are derived from typical hardwood containing 6.5% hydrogen, 50% carbon. Moisture content, 20%.

1. Many moisture meters give dry basis moisture readings. We are working with moist basis moisture here. To convert dry to moist basis use this formula:

$$\text{Moist Basis reading} = \frac{\text{dry basis reading}}{(1 + \text{dry basis reading})}$$

APPENDIX C

QUALITY ASSURANCE AND PROPAGATION OF ERROR CALCULATIONS

Quality Assurance

1.0 Quality Assurance -- Particulate Emission Levels

Particulate emission levels are being reported in four different formats. These are: (1) mass particles/mass dry wood; (2) mass particles/heat output; (3) mass particles/time of stove operation; and (4) mass particles/volume of flue gas. Complete equations for the calculation of these parameters and for the calculation of their associated uncertainties are presented in Attachment C-1. Accuracy and precision estimates were made for all primary parameters used to calculate the particulate emission values. The accuracy and precision estimates were based on manufacturer's specifications and from field and laboratory experience. The accuracy and precision estimates are listed in Table C-1. Standard propagation of error treatment of the data was used to estimate the overall accuracy and precision associated with the final calculated particulate levels. Attachment C-2 lists the calculations used for other parameters used in the study, including mean flue temperature, catalyst light-off, wood moisture content, and burn rate.

1.1 Accuracy

A conservative estimate (i.e., maximum probable bias) was made of the systematic error for each primary parameter from which a propagated accuracy value was determined. Propagated error values were calculated for every emission data set. Accuracy is defined as a systematic bias, and the same biases would manifest themselves throughout the entire study since the same type of instrumentation was utilized at all homes, and, consequently, accuracy would not be an issue in intra-study comparisons, e.g., comparing catalyst vs. non-catalyst emission values.

The mass particles/volume of flue gas format had the lowest (best) relative accuracy among the four methods of reporting particulate emission levels. This was due simply to the fact that fewer parameters were necessary to calculate the mass/volume value and that the oxygen content, which has a higher uncertainty level associated with it, was not needed for the mass/volume calculation, whereas it is needed to calculate the other three emission rates.

1.2 Precision

An estimate of the limit of error (1% confidence limit) was made for each primary parameter from which a propagated precision value was determined. The limit of error (λ) is equal to 2.6 times the standard deviation (σ) for a normal distribution. The limit of error was used in the estimation of the precision (random error) of the primary parameters since it is conceptually easier to estimate than a standard deviation. As with the accuracy estimates, manufacturer's specifications and field and laboratory experience were taken into consideration in making the estimates. The precision estimates (λ) for each primary parameter are listed in Table C-1. After an overall precision value was calculated by the standard propagation of error technique, the value was divided by 2.6 to put it in the more meaningful standard deviation form. The precision typically associated with the standard U.S. EPA Method 5 technique is generally recognized as being approximately 20%.

1.3 Representativeness

Inherent in the design of the AWES/Data LOG'r sampling approach is a high degree of representativeness. By sampling for one minute out of thirty for a week-long period, a long-term integrated sample is obtained. Moreover, by the in situ sampling of the emissions under actual home use conditions, samples representative of "real world" emissions were obtained.

Attachment C-1

Calculations and Propagation of Errors - Particulate Data

Parameters - Particulate Data

1.	MP	Mass particles (total)
	MF	Mass particles on filter
	MRMC	Mass particles from methylene chloride rinse
	MRM	Mass particles from methanol rinse
	MX	Mass particles from XAD-2
	MFB	Mean mass particles in field blanks
2.	SV	Specific stoichiometric volume (corrected for stove type)
3.	FR	Sampler flow rate
4.	SD	Sampling duration
5.	$\%O_2$	Flue gas O_2
6.	HC	Specific heat content
7.	EF	Efficiency factor
8.	MDW	Mass of wood, dry basis
9.	SP	Sampling period

1. Mass Particles

$$(MP) = MF + MRMC + MRM + MX - MFB$$
$$\Delta MP = \Delta MF + \Delta MRMC + \Delta MRM + \Delta MX + \Delta MFB$$

2. Mass Particles / Mass Dry Wood $= \dfrac{MP \times SV}{FR \times SD \times (1 - \%O_2/20.9\%)}$

Propagated error =

$$\Delta MP \left[\frac{SV}{FR \times SD \times (1 - \%O_2/20.9\%)} \right] + \Delta SV \left[\frac{MP}{FR \times SD \times (1 - \%O_2/20.9\%)} \right]$$

$$+ \Delta FR \left[\frac{MP \times SV}{FR^2 \times SD \times (1 - \%O_2/20.9\%)} \right] + \Delta SD \left[\frac{MP \times SV}{FR \times SD^2 \times (1 - \%O_2/20.9\%)} \right]$$

$$+ \Delta O_2\% \left[\frac{MP \times SV}{FR \times SD \times 20.9\% \times (1 - \%O_2/20.9\%)^2} \right]$$

3. Mass Particles / Heat Output $= \dfrac{MP \times SV}{FR \times SD \times HC \times EF \times (1 - \%O_2/20.9\%)}$

Propagated Error =

$$\Delta MP \left[\frac{SV}{FR \times SD \times HC \times EF \times (1 - \%O_2/20.9\%)} \right] + \Delta SV \left[\frac{MP}{FR \times SD \times HC \times EF \times (1 - \%O_2/20.9\%)} \right]$$

$$+ \Delta FR \left[\frac{MP \times SV}{FR^2 \times SD \times HC \times EF \times (1 - \%O_2/20.9\%)} \right] + \Delta SD \left[\frac{MP \times SV}{FR \times SD^2 \times HC \times EF \times (1 - \%O_2/20.9\%)} \right]$$

$$+ \ \Delta HC \left[\frac{MP \times SV}{FR \times SD \times HC^2 \times EF \times (1-\%O_2/20.9\%)}\right] + \ \Delta EF \left[\frac{MP \times SV}{FR \times SD \times HC \times EF^2 \times (1-\%O_2/20.9\%)}\right]$$

$$+ \ \Delta O_2\% \left[\frac{MP \times SV}{FR \times SD \times HC \times EF \times 20.9\% \times (1-\%O_2/20.9\%)^2}\right]$$

4. Mass Particulate Emissions / Time Stove Operations (SP) =

$$\frac{MP \times SV \times MDW}{FR \times SD \times SP \times (1-\%O_2/20.9\%)}$$

Propagated error =

$$\Delta MP \left[\frac{SV \times MDW}{FR \times SD \times SP \ (1-\%O_2/20.9\%)}\right] + \ \Delta SV \left[\frac{MP \times MDW}{FR \times SD \times SP \ (1-\%O_2/20.9\%)}\right]$$

$$+ \ \Delta MDW \left[\frac{MP \times SV}{FR \times SD \times SP \ (1-\%O_2/20.9\%)}\right] + \ \Delta FR \left[\frac{MP \times SV \times MDW}{FR^2 \times SD \times SP \ (1-\%O_2/20.9\%)}\right]$$

$$+ \ \Delta SD \left[\frac{MP \times SV \times MDW}{FR \times SD^2 \times SP \ (1-\%O_2/20.9\%)}\right] + \ \Delta SP \left[\frac{MP \times SV \times MDW}{FR \times SD \times SP^2 \ (1-\%O_2/20.9\%)}\right]$$

$$+ \ \Delta O_2\% \left[\frac{MP \times SV \times MDW}{FR \times SD \times SP \times 20.9\% \ (1-\%O_2/20.9\%)^2}\right]$$

5. Mass particles / volume = $\frac{MP}{FR \times SD}$

Note: Standard temperature at which orifice mass flows are reported is 20°C.

Propagated error = $\Delta MP \left[\frac{1}{FR \times SD}\right] + \Delta FR \left[\frac{MP}{FR^2 \times SD}\right] + \Delta SD \left[\frac{MP}{FR \times SD^2}\right]$

Table C-1

Precision and Accuracy Estimates

Parameter	Estimated Precision (λ)	Estimated Accuracy	Comments
1. ΔMP	Sum of a,b,c,d*, & e	Sum of a,b,c,d* & e	
a. ΔMF	± 1 mg	± 0.1 mg	
b. $\Delta MRMC$	± 2 mg	± 0.5 mg	weighing errors
c. ΔMRM	± 2 mg	± 0.5 mg	
d. ΔMX	± 20% (relative)*	± 50% (relative)*	polar compounds, surrogate standards
e. ΔMFB	± 26.0 mg	± 2.5	ΔMP for field blanks
2. ΔSV	180 (constant)	± 250 litres/kg dry wood	range in calculated values
3. ΔFR	± 0.2 litres/min.	± 0.3 litres/min.	field observations, wet basis
4. ΔSD	± 1.78% relative*	± 1.78% relative*	6 min. out of 336 min. 1 sec. out of 1 min.
5. $\Delta \%O_2$	± 1%O_2 (absolute)	± 2%O_2 (absolute)	field data
6. ΔHC	1.0×10^6 joules/kg (constant)	± 1.0×10^6 joules/kg	range in measured values
7. ΔEF	± 0.03 (constant)	± 0.1	laboratory experience
8. ΔMDB	± 3% (absolute)	± 5% (absolute)	<25% moisture
	± 4% (absolute)	± 5% (absolute)	25-35% moisture
	± 15% (absolute)	± 15% (absolute)	> 35% moisture Manf. specs & field data
9. ΔSP	± 0.3% (relative)*	± 1.0% (relative)*	field data
10. Δindoor temp	± 2°F (1.2°C)	± 4°F (2.5°C)	Manf. specs.
11. Δflue & catalyst temp	± 3°F (1.9°C) or 0.5% (relative)* whichever is greater	± 6°F (3.8°C) or 1.0% (relative)* whichever is greater	600°F threshold for relative error, Manf. specs

Attachment C-2

Miscellaneous Parameters and Notes

1. Flue temp. (TC_1)

   $\bar{x} \pm S.D.$ weekly (above 100°F)

2. Percent of time combustor is operational $(TC_2 > 500°F)$ during stove use $(TC_1 > 100°F)$.

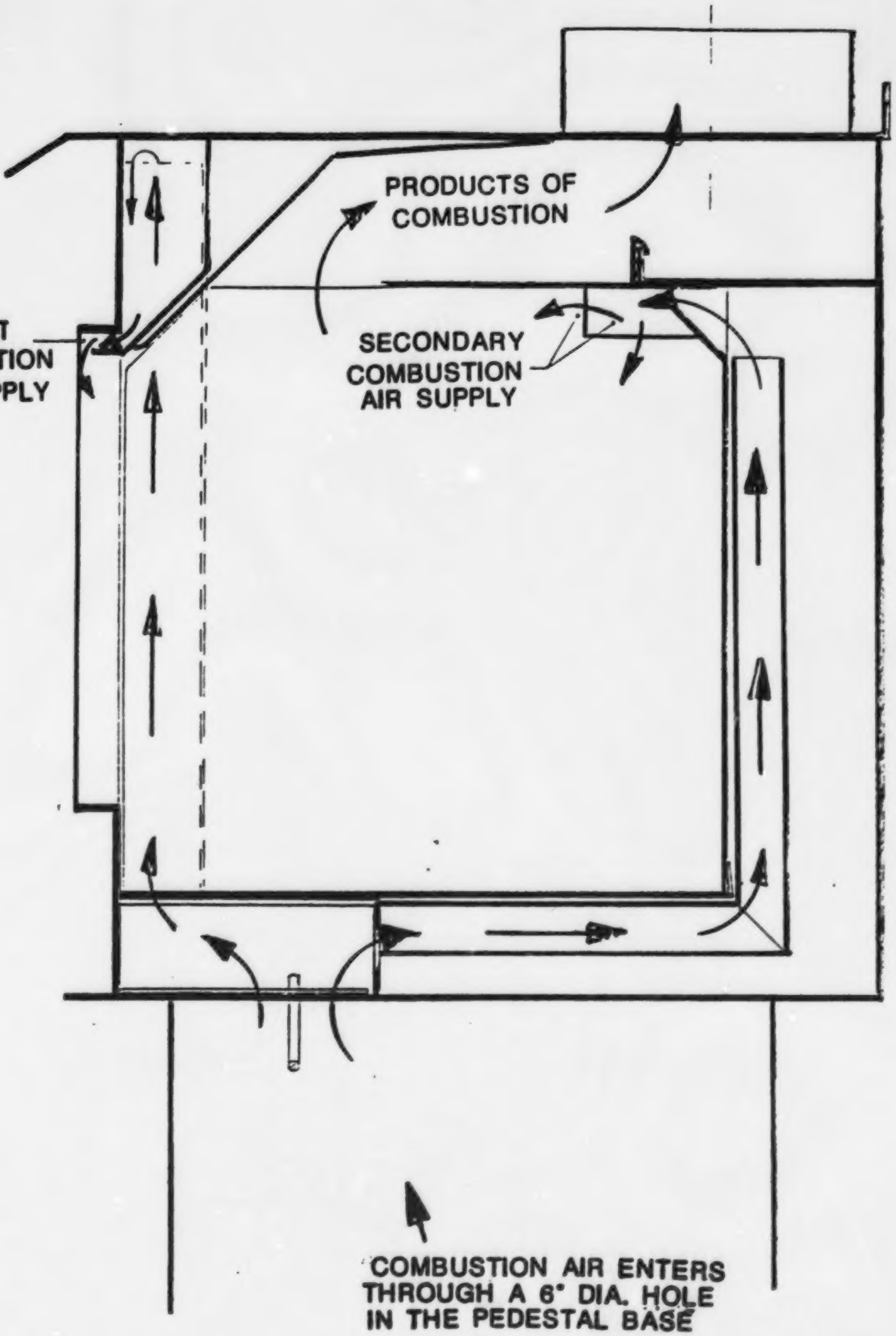
3. $$MDW = \frac{MWW}{(1+WDB)}$$

   MDW = Mass dry wood
   MWW = Mass wet wood
   WDB = Water content of wood, dry basis, as fractional percent

   $$\Delta MDW = \Delta MWW \left[\frac{1}{(1+WDB)} \right] + \Delta WDB \left[\frac{MWW}{(1+WDB)^2} \right]$$

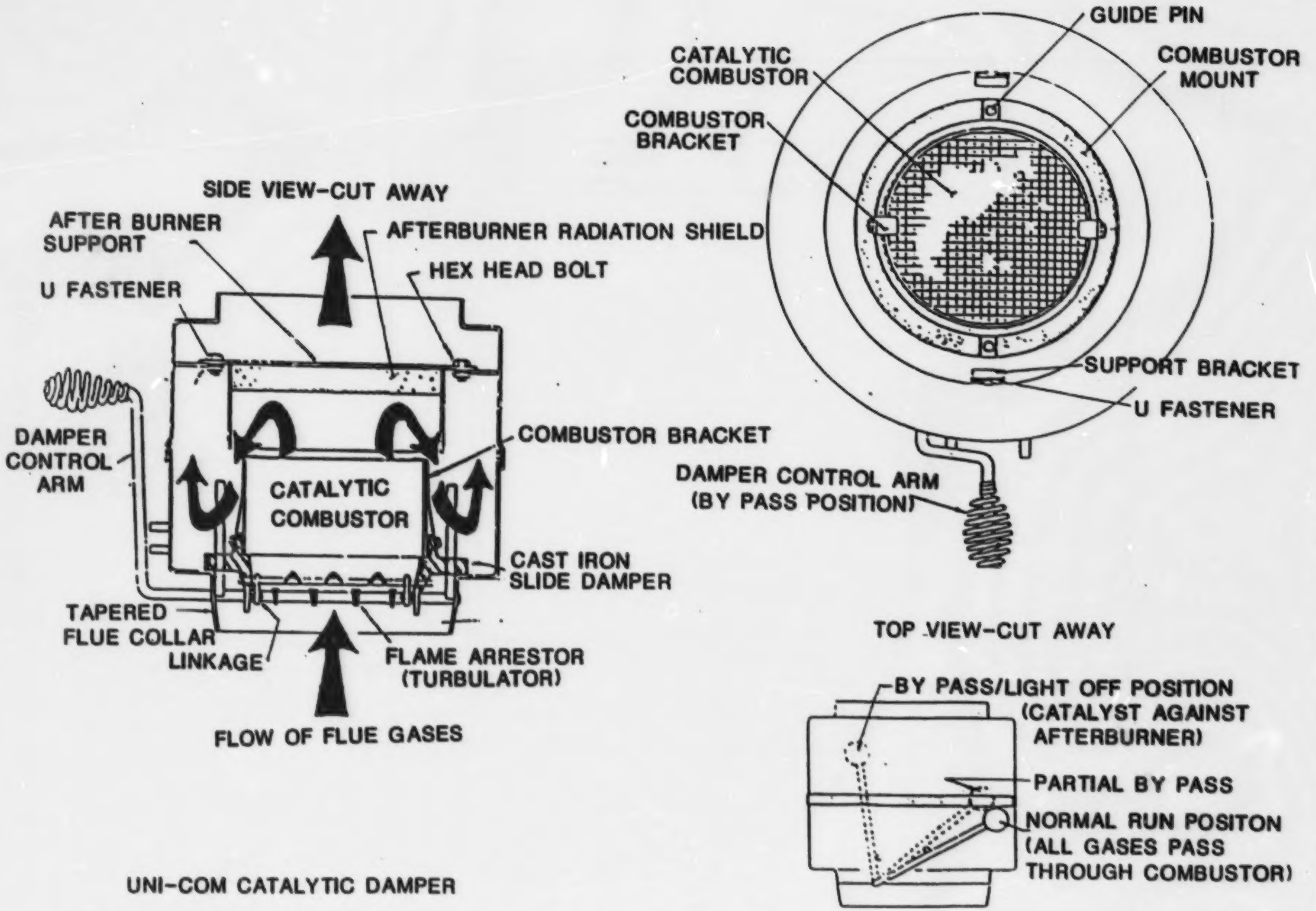
4. Burn rate

   Kg dry wood / hours that $TC_1 > 100°F$

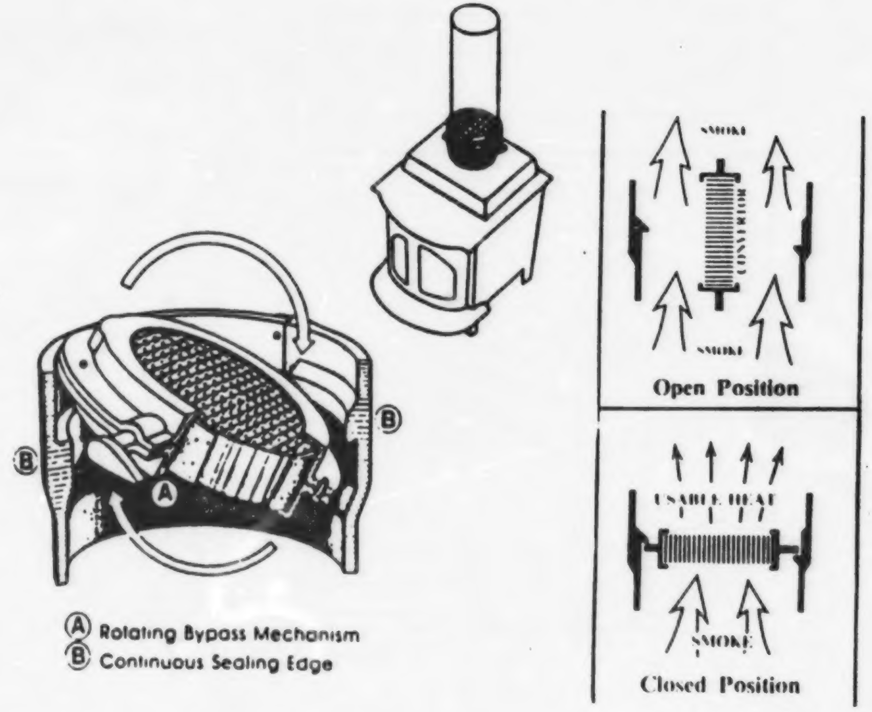

PRODUCTS OF COMBUSTION
FRONT COMBUSTION AIR SUPPLY
SECONDARY COMBUSTION AIR SUPPLY
COMBUSTION AIR ENTERS THROUGH A 6" DIA. HOLE IN THE PEDESTAL BASE

OSBURN IMPERIAL 2000

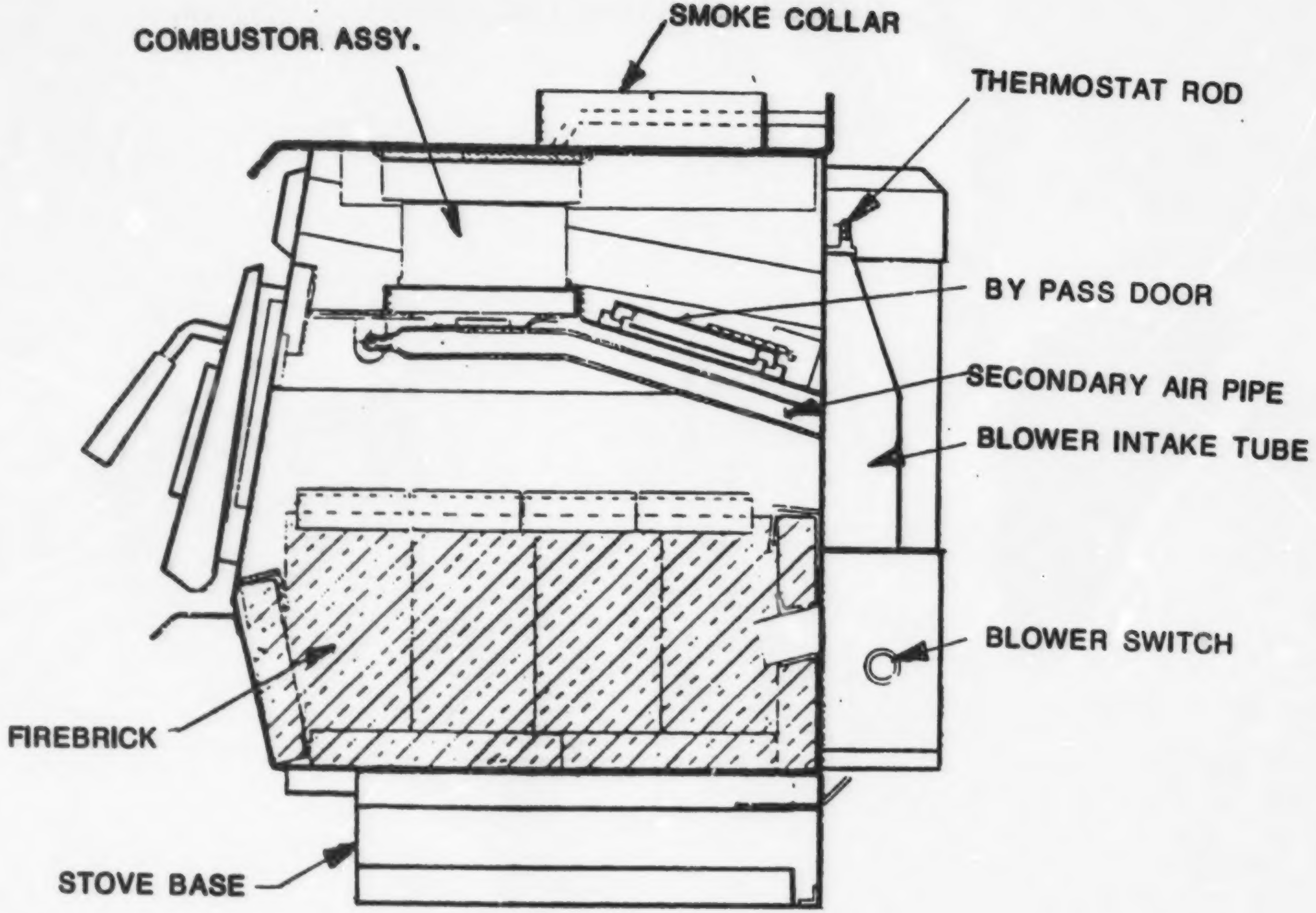
COMBUSTION AIR FLOW


SIDE VIEW-CUT AWAY
AFTER BURNER SUPPORT
U FASTENER
AFTERBURNER RADIATION SHIELD
HEX HEAD BOLT
DAMPER CONTROL ARM
COMBUSTOR BRACKET
CATALYTIC COMBUSTOR
CAST IRON SLIDE DAMPER
TAPERED FLUE COLLAR
LINKAGE
FLAME ARRESTOR (TURBULATOR)
FLOW OF FLUE GASES
GUIDE PIN
CATALYTIC COMBUSTOR
COMBUSTOR MOUNT
COMBUSTOR BRACKET
SUPPORT BRACKET
U FASTENER
DAMPER CONTROL ARM (BY PASS POSITION)
TOP VIEW-CUT AWAY
BY PASS/LIGHT OFF POSITION (CATALYST AGAINST AFTERBURNER)
PARTIAL BY PASS
NORMAL RUN POSITON (ALL GASES PASS THROUGH COMBUSTOR)

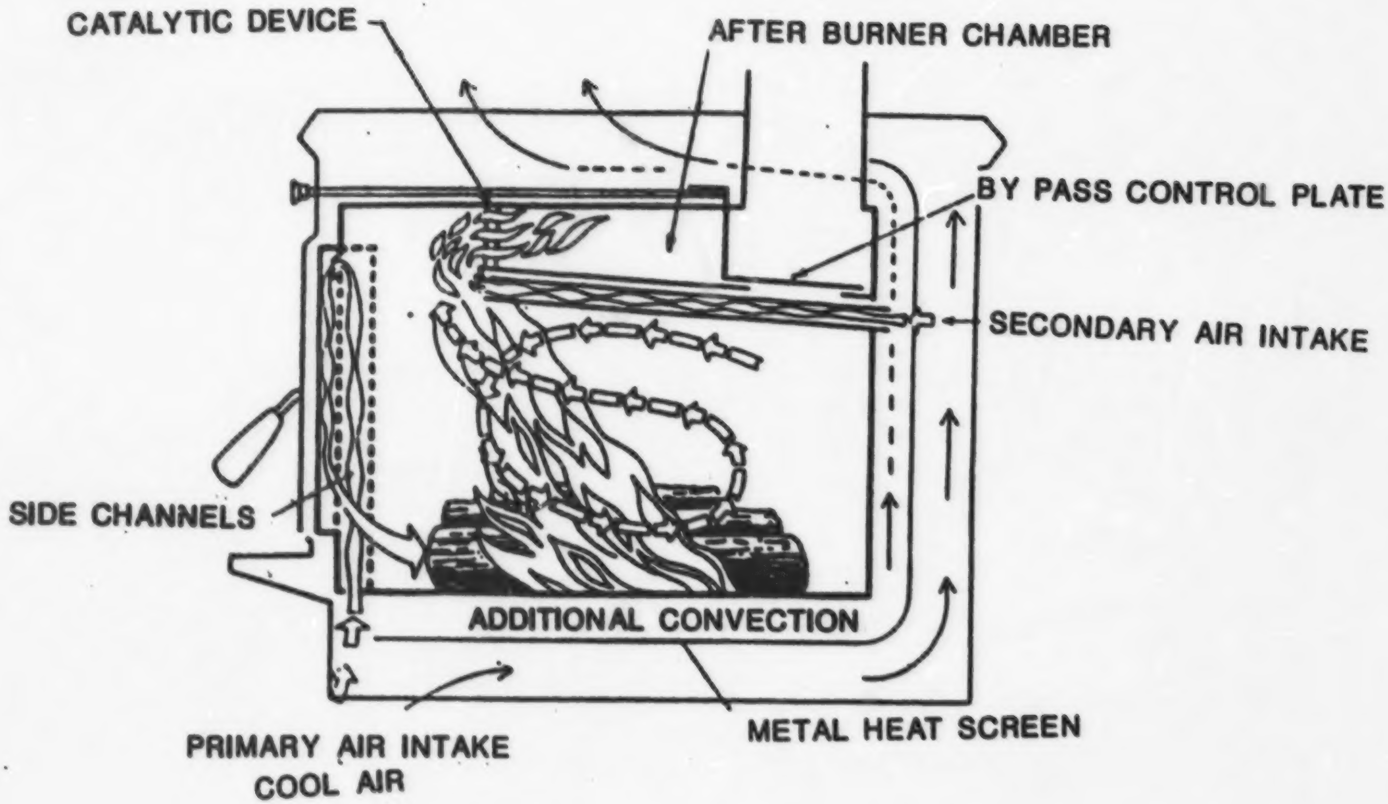
UNI-COM CATALYTIC DAMPER


B
B
A
SMOKE
CONVERTOR
SMOKE
Open Position
USABLE HEAT
SMOKE
Closed Position
Ⓐ Rotating Bypass Mechanism
Ⓑ Continuous Sealing Edge

NU-TEC™ CATALYTIC CONVERTOR RETROFIT


COMBUSTOR ASSY.
SMOKE COLLAR
THERMOSTAT ROD
BY PASS DOOR
SECONDARY AIR PIPE
BLOWER INTAKE TUBE
BLOWER SWITCH
FIREBRICK
STOVE BASE

BLAZE KING CATALYTIC FREESTANDING STOVE CUT AWAY VIEW


CATALYTIC DEVICE
AFTER BURNER CHAMBER
BY PASS CONTROL PLATE
SECONDARY AIR INTAKE
SIDE CHANNELS
ADDITIONAL CONVECTION
METAL HEAT SCREEN
PRIMARY AIR INTAKE
COOL AIR

BURNING LOG TURBO 10 COMBUSTION AIR FLOW DIAGRAM

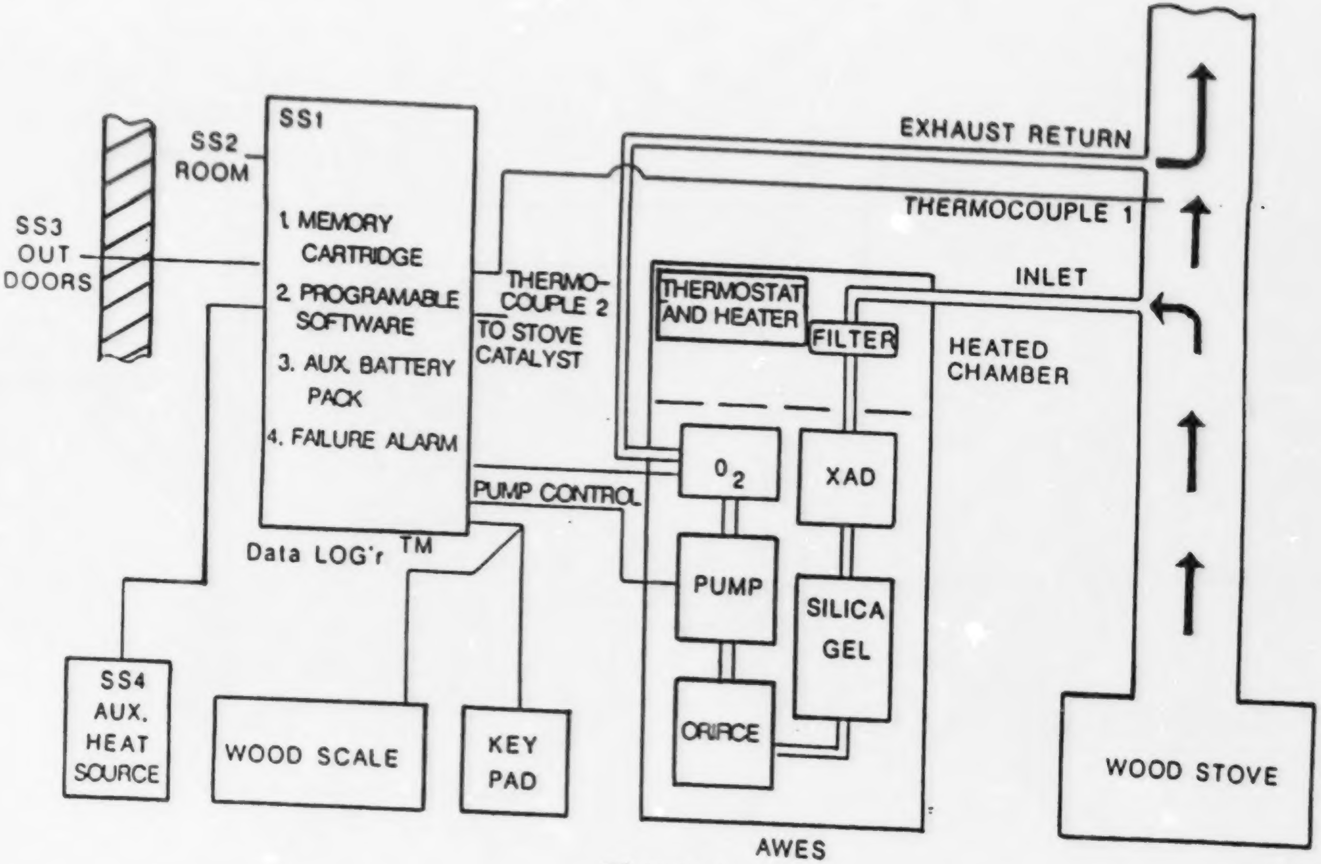

SS1
SS2 ROOM
SS3 OUT DOORS
1. MEMORY CARTRIDGE
2. PROGRAMABLE SOFTWARE
3. AUX. BATTERY PACK
4. FAILURE ALARM
Data LOG'r TM
THERMO-COUPLE 2
TO STOVE CATALYST
PUMP CONTROL
SS4 AUX. HEAT SOURCE
WOOD SCALE
KEY PAD
EXHAUST RETURN
THERMOCOUPLE 1
INLET
THERMOSTAT AND HEATER
FILTER
HEATED CHAMBER
0₂
XAD
PUMP
SILICA GEL
ORIFICE
AWES
WOOD STOVE

Figure 1

AWES/Data LOG'r System

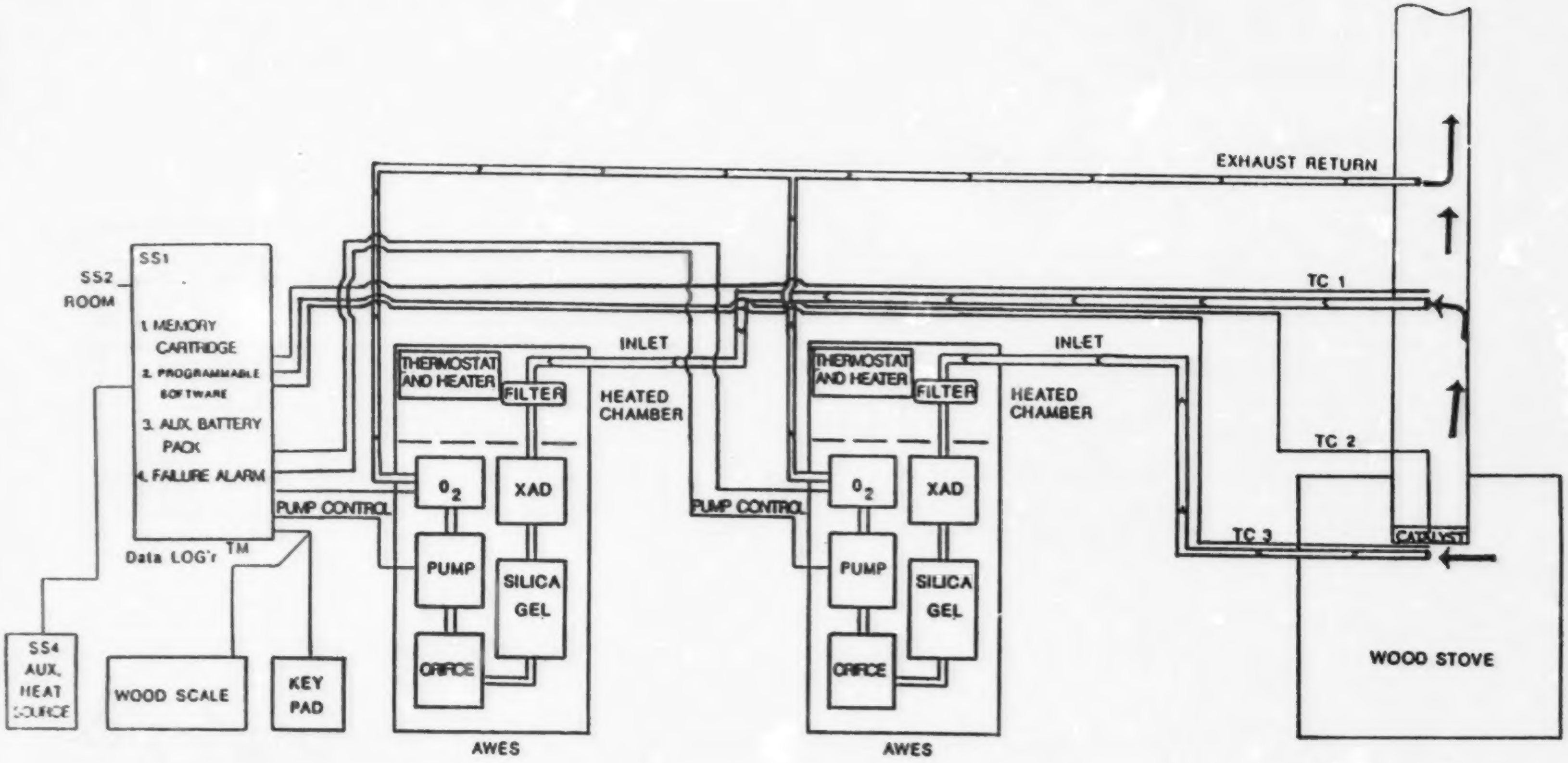
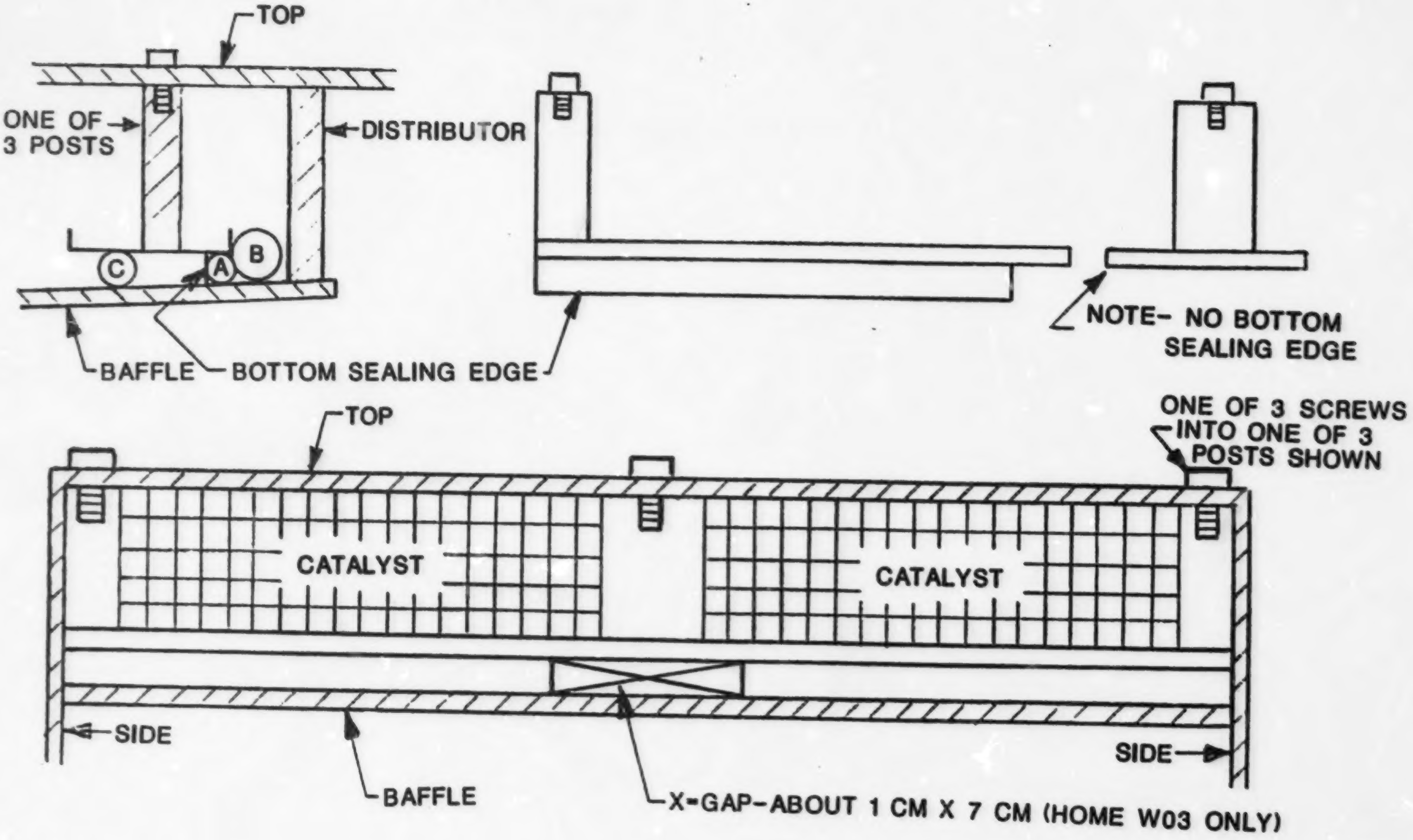

EXHAUST RETURN
TC 1
TC 2
TC 3
CATALYST
WOOD STOVE
INLET
HEATED CHAMBER
THERMOSTAT AND HEATER
FILTER
0_2
XAD
PUMP
SILICA GEL
ORIFICE
AWES
INLET
HEATED CHAMBER
THERMOSTAT AND HEATER
FILTER
0_2
XAD
PUMP
SILICA GEL
ORIFICE
AWES
PUMP CONTROL
PUMP CONTROL
SS1
SS2
ROOM
1. MEMORY CARTRIDGE
2. PROGRAMMABLE SOFTWARE
3. AUX. BATTERY PACK
4. FAILURE ALARM
Data LOG'r TM
SS4 AUX. HEAT SOURCE
WOOD SCALE
KEY PAD

Figure 2

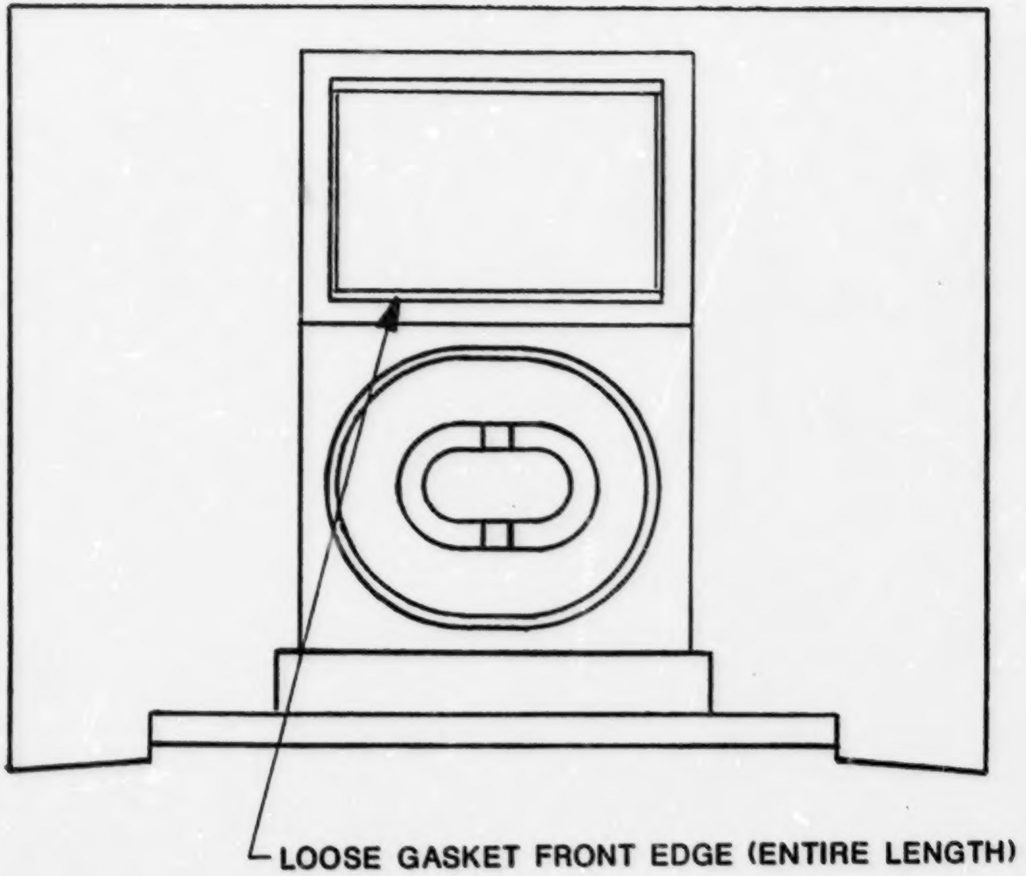
Dual AWES/Data LOG'r System


TOP
ONE OF 3 POSTS
DISTRIBUTOR
C
A
B
BAFFLE
BOTTOM SEALING EDGE
NOTE- NO BOTTOM SEALING EDGE
TOP
ONE OF 3 SCREWS INTO ONE OF 3 POSTS SHOWN
CATALYST
CATALYST
SIDE
SIDE
BAFFLE
X-GAP-ABOUT 1 CM X 7 CM (HOME W03 ONLY)

HOME W03-GASKET B ONLY

HOME W14-GASKET A & C ONLY

CATALYTIC COMBUSTOR
SCHEMATIC-TURBO 10
FIGURE 3

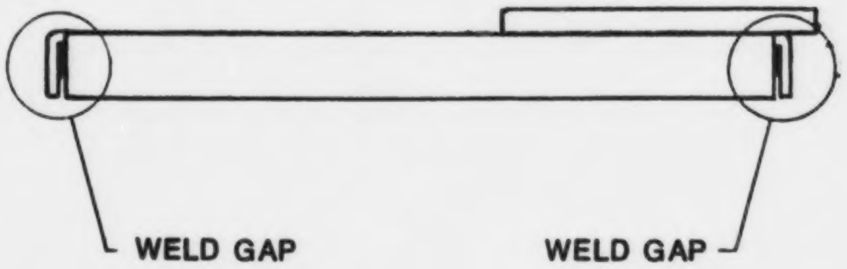

LOOSE GASKET FRONT EDGE (ENTIRE LENGTH)

BY PASS DOOR GASKET-BLAZE KING

FIGURE 4

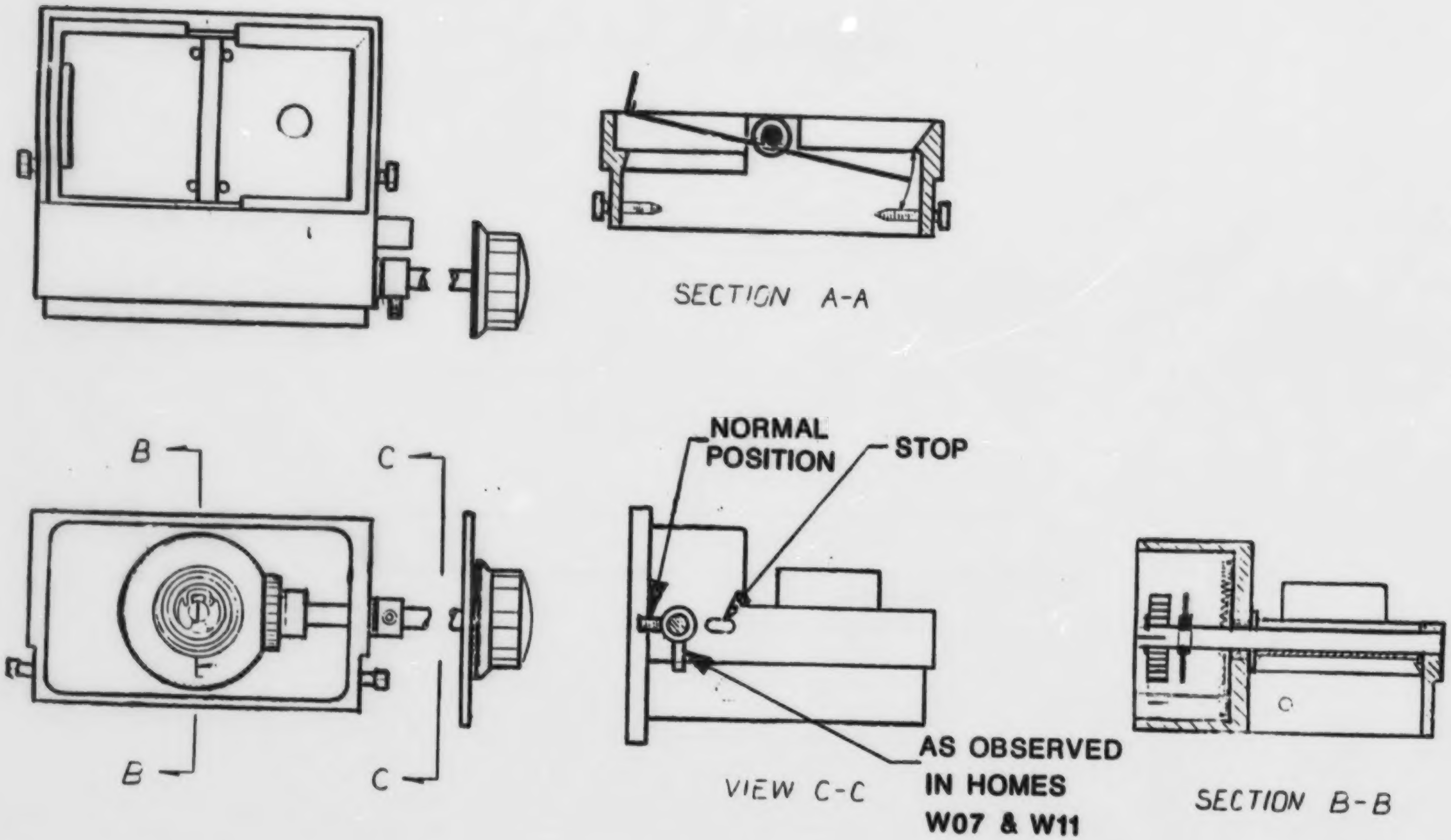
APPENDIX D

SCHEMATICS OF NEW WOODHEAT TECHNOLOGIES


WELD GAP
WELD GAP

BY PASS DOOR ASSEMBLY

FIGURE 5


SECTION A-A
B
B
C
C
NORMAL POSITION
STOP
VIEW C-C
AS OBSERVED IN HOMES W07 & W11
SECTION B-B

STOVE THERMOSTAT ASSEMBLY

FIGURE 6

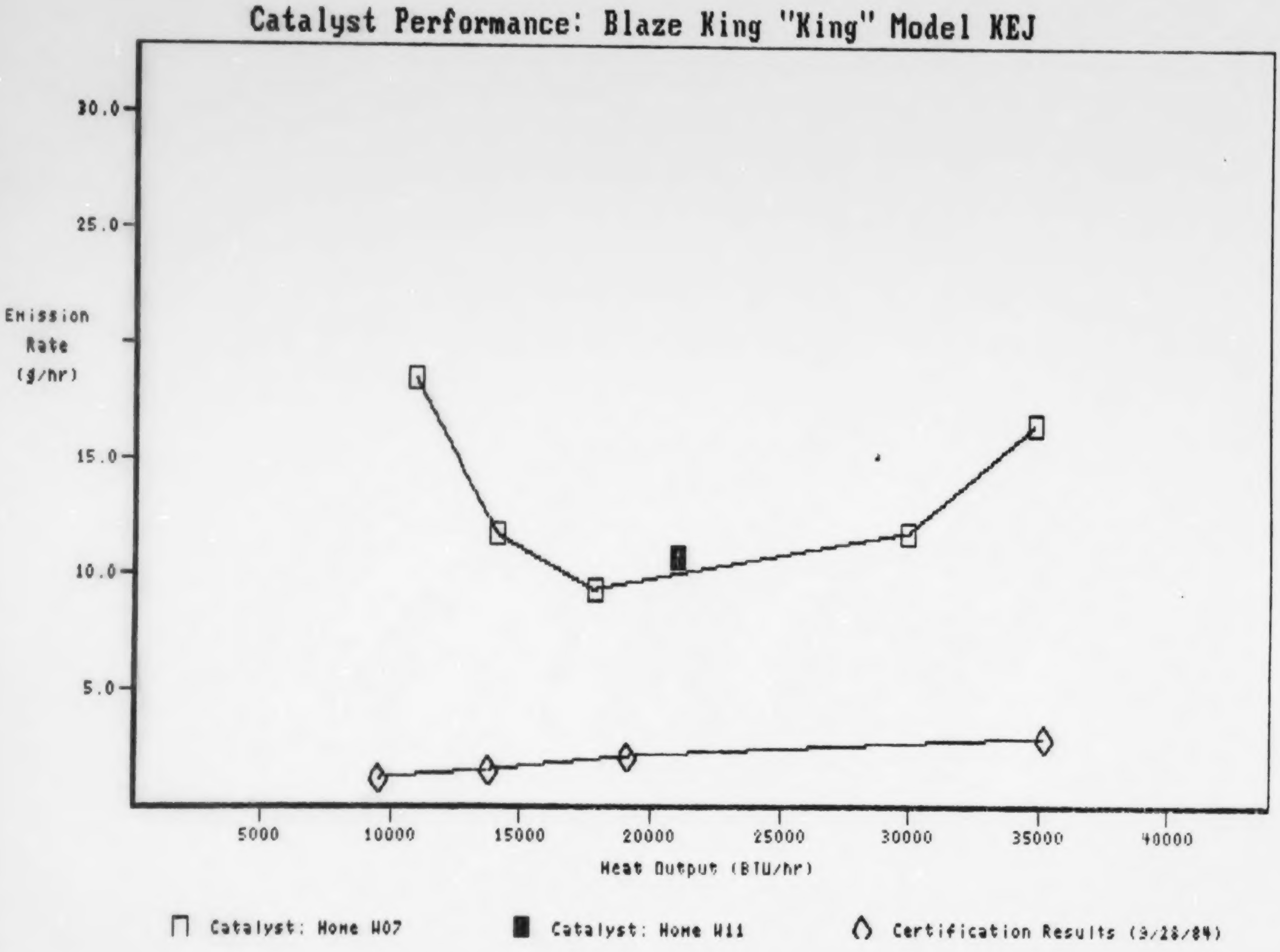

Catalyst Performance: Blaze King "King" Model KEJ
Emission Rate (g/hr)
30.0
25.0
15.0
10.0
5.0
5000
10000
15000
20000
25000
30000
35000
40000
Heat Output (BTU/hr)
□ Catalyst: Home H07
■ Catalyst: Home H11
◇ Certification Results (3/28/84)

FIGURE 7

APPENDIX E

LABORATORY TEST DATA REPORTS: BLAZE KING "KING" WITH CATALYST FROM HOMES W07 AND W11

AND

LETTER REGARDING CORRECTIVE ACTIONS BY BLAZE KING CANADA LTD.

TEST DATA REPORT

ENERGY, MINES

and RESOURCES CANADA

SE188-01

Prepared for: Energy, Mines and Resources Canada
2078 Second Avenue
Whitehorse, Yukon
Canada

Prepared by: OMNI Environmental Services, Inc.
10950 SW Fifth Street, Suite 160
Beaverton, OR 97005

September 3, 1987

SE188-01

OMNI
ENVIRONMENTAL
SERVICES, INC.

Consulting
Engineering
Testing

OMNI™

This report presents results of testing procedures performed in accordance with referenced standards and professional diligence and care. Reported performance values reflect the conditions of laboratory test criteria and do not necessarily indicate the total range of appliance capability. Consumer installation and operating configurations, fueling and operator practices as well as atmospheric conditions can affect in-field performance.

This report has been reviewed and approved by:

Mark S. Fisher 9/4/87

Mark Fisher
Emission Testing Manager
OMNI Environmental Services, Inc.

SE188-01

Energy, Mines, and Resources Canada

Field Combustor Tests

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SUMMARY

Energy, Mines and Resources Canada retained OMNI Environmental Services, Inc., to perform emissions and efficiency testing on the two Matsushita catalysts distributed by Technical Glass Products. These catalysts were installed in the Woodcutters Blaze King "King" woodstove (Model KEJ) This stove was identical to the stoves used in Whitehorse homes W07 and W11. This appliance was tested in accordance with the Oregon Department of Environmental Quality (DEQ) "Standard Method for Measuring the Emissions and Efficiency of Woodstoves," dated June 8, 1984, and the Environmental Protection Agency (EPA) 40 CFR Part 60, Subpart AAA — Standard of Performance for Residential Wood Heaters, as published for comment on Wednesday, February 19, 1987. Emissions were measured using EPA Method 5G. The testing was performed August 13 and 19, 1987, at the OMNI Solid Fuels Testing Laboratory in Beaverton, Oregon.

Two test runs were completed, and efficiencies and particulate emissions were measured. Both runs were conducted using Technical Glass Products Model F8 catalysts, manufactured by Matsushita Battery of Japan. Run 1 was conducted using the catalyst from home W07 (OMNI code OMW07), and Run 2 using the catalyst from home W11 (OMNI code OMW11) model. Heat outputs for runs 1 and 2 were 29,920 and 21,057 Btus per hour. Overall efficiencies were 66.1 and 70.1 percent, respectively. From EPA Method 5G, particulate emissions were measured to be 11.8 and 10.8 grams per hour, respectively.

Primary air settings used for the test runs and the five minute start-up procedure for each run are as shown below:

Run #	Thermostat Setting	Five-Minute Start-Up Procedure	
1	$2^{5}/_{8}$	Door: Bypass: Primary air: Fan:	ajar 2 minutes ajar 2 minutes set at full high for 4 minutes, then set at test setting high for test
2	slightly under setting 2	Door: Bypass: Primary air: Fan:	ajar 1 minute open for 1 minute set at full high for 4 minutes, then set to test setting by 4.3 minutes high for test

CATALYST DESCRIPTION (Refer to "Whitehorse Efficient Woodheat Demonstration" Report, PS256)

Model: Technical Glass Products (Matsushita)
Model No.: 86-04 Model F8
Field No.: W07
Size: oval, maximum dimensions:

$7^1/_8 \times 8^5/_8$ (outside can dimension)

$6^7/_8 \times 8^3/_8$ (ceramic dimension)

2" thickness

Cells per in^2: 16
Aging time or
Field Description: Whitehorse Project
Run: 1

Model: Technical Glass Products (Matsushita)
Model No.: 86-04 Model F8
Field No.: W11
Size: oval, maximum dimensions:

$7^1/_8 \times 8^5/_8$ (outside can dimension)

$6^7/_8 \times 8^3/_8$ (ceramic dimension)

2" thickness

Cells per in^2: 16
Aging time or
Field Description: Whitehorse Project
Run: 2

During the testing of these combustors, every attempt was made to ensure that there was no leakage around the combustor or the bypass. Before and after each test a check for leaks was performed by placing a 500-watt light in the firebox and inspecting the critical seals for light leakage.

Prior to Run 1, the bypass gasket was replaced with a new one from a Woodcutter's distributor. After the initial installation of the combustor (OMW07) for Run 1 using one wrap of interam, it was determined that the combustor would not seal as evidenced by large gaps between the interam and the combustor cup lip. Therefore, two wraps of interam with additional pieces on the right and left were used. This resulted in an initially tight fit.

But, after two hours of burning, another inspection was made and leakage was observed. The combustor was then wrapped with a single wrap that overlapped itself. Again, after two hours of burning, a leak check was performed and this time, there was no leakage observed.

Test Run 1 was conducted attempting to achieve a 19,000 Btu/hr heat output, which was representative of average heat output in homes W07 and W11. However, due to changes in the reference marks on the air control knob from the original certification test series, the setting produced 29,920 Btu/hr. After the test, the combustor and bypass were again inspected for leakage. No leakage was observed around the combustor. Unfortunately, though, the bypass had been disengaged after the completion of the test and prior to inspection, so it was impossible to verify if there was any leakage during the test. Some leakage was observed after the bypass had been engaged and disengaged a few times. However, this doesn't confirm any leakage during Run 1.

Prior to Run 2, the second combustor was installed again with various amounts of interam. Several attempts were made to seal the combustor by burning the stove and then inspecting it for leaks. Finally, a single wrap of interam with a three-inch piece overlapping the butt joint was used. After burning for two hours and inspecting the seal, it was observed to be a tight fit. Run 2 was conducted resulting in 21,057 Btu/hr.

Inspection of the unit after the test showed that the bypass was not leaking. However, the combustor showed a pin head leakage of light at the butt joint.

It should be noted that all inspections of the combustor and bypass leakage were made by looking down through the flue collar. This allowed for a thorough inspection of the bypass. However, due to the stove design, only the back edge of the combustor could be inspected for leakage. The front edge is inaccessible for visual observation.

The combustors were handled with extreme care. However, during one of the installations or removals, the in-combustor thermocouple cracked off a piece of the OMW11 combustor. One side of one cell was broken off approximately down halfway through the combustor.

Summary Tables, reduced data results, and calorimeter room raw data sheets are included for each run.

SUMMARY TABLE 1

Energy, Mines and Resources Canada

Project SE188-01

RESULTS

RUN #	PARTICULATE EMISSION GM/HR	HEAT OUTPUT**	OVERALL EFFICIENCY*	COMBUSTION % EFFICIENCY	HEAT TRANSFER % EFFICIENCY
1	11.8	29,920	66.1	81.5	81.2
2	10.8	21,057	70.1	84.1	83.3

* Corrected for stove thermal mass

** Btu per hour

SUMMARY TABLE 2

Energy, Mines and Resources Canada

Project SE188-01

FUEL AND OPERATING PARAMETERS

RUN #	BURN RATE KG/HR (DRY)	FUEL H_2O %(WET) TEST LOAD	HHV*	TIME (MIN)	POUNDS BURNED
1	2.34	18.03	8,765	260	27.3
2	1.56	18.37	8,765	410	28.7

* Higher heating value (Btu/1b) (assumed value)

SUMMARY TABLE 3

Energy, Mines and Resources Canada

Project SE188-01

CARBON MONOXIDE EMISSIONS

RUN #	GRAMS CO/KG	GRAMS CO/HOUR
1	79.17	185.45
2	57.94	90.11

SUMMARY TABLE 4

Energy, Mines and Resources Canada

Project SE188-01

FLUE GAS MEASUREMENTS

RUN #	TEMP °F	H_2O%	O_2%	CO_2%	CO%	EXCESS AIR %	FLOW RATE CHO DSCF/MIN	DRAFT IN. H_2O	AIR/FUEL RATIO LB/LB
1	257	12.62	7.90	12.28	1.07	55.73	8.82	-0.045	7.62
2	210	10.09	10.25	10.09	0.61	92.60	7.47	-0.035	9.85

SUMMARY TABLE 5

Energy, Mines and Resources Canada

Project SE188-01

AVERAGE STOVE TEMPERATURES OVER TEST CYCLE *

	STOVE SURFACE						COMBUSTOR		
RUN #	TOP	BOTTOM	LEFT	RIGHT	BACK	FIREBOX	UPSTREAM	WITHIN	DOWNSTREAM
1	419	258	n/a	436	307	925	1,019	1,140	935
2	332	243	331	371	211	n/a	797	1,094	785

*** All temperatures in degrees Fahrenheit**

```
                    EPA METHOD 5G RESULTS

                   CLIENT ENERGY MINES AND RESOURCES CANADA
                    MODEL KEJ-1101
                PROJECT # SE188-1
                     RUN# 1
                     DATE 8-13-87
            FILTER HOLDER B
```

FINAL

```
                    EPA METHOD 5G RESULTS

***********************************************************************
PARTICULATE CONCENTRATION (DRY-STANDARD)..  0.0011 (GRAMS/DSCF)
PARTICULATE EMISSION RATE.................   9.530 (GRAMS/HOUR)
ADJUSTED EMISSIONS........................    11.8 (GRAMS/HOUR)
***********************************************************************

TUNNEL TEMPERATURE AVERAGE................      88 (DEGREES FAHRENHEIT)

AVERAGE DELTA P RUN DATA..................   0.040 (INCHES H2O)

(Vm)TOTAL SAMPLE VOLUME (METER CONDITIONS) 131.877 (CUBIC FEET)
AVERAGE GAS METER TEMPERATURE.............      83 (DEGREES FAHRENHEIT)
(vs)AVG. GAS VELOCITY IN DILUTION TUNNEL..   13.48 (FEET/SECOND)
(Qsd)AVG. GAS FLOW RATE IN DILUTION TUNNEL 8771.03 (DSCFH)
(Vmstd)TOTAL SAMPLE VOL. (STD. CONDITIONS) 126.913 (DSCF)
-----------------------------------------------------------------------
(mn) TOTAL PARTICULATES...................   137.9 (MG)
AVERAGE DELTA H...........................   0.535 (INCHES H2O)
TOTAL TIME OF TEST........................     260 (MINUTES)
```

```
                          TABLE 1

 ---------------------------------------------------------------------------

 RESULTS OF EFFICIENCY TESTING ON THE ENERGY MINES AND RESOURCES CANADA
  WOOD STOVE

 RUN NUMBER 1   PROJECT NUMBER SE188-1  SERIAL NUMBER C1106

 DATE OF TEST: 8-13-87          STOVE MODEL: KEJ-1101
 ---------------------------------------------------------------------------


                     AVERAGE EFFICIENCIES

 ***************************************************************************
 * COMBUSTION= 81.5  % * HEAT TRANS.= 81.2  % * OVERALL= 66.1  %
  *
 ***************************************************************************


                          EMISSIONS

 ***************************************************************************
 * PARTICULATES:       0.000  (grams/Kg-wood)     0.000  (grams/hour)      *
 * CARBON MONOXIDE:  79.174  (grams/Kg-wood)   185.450  (grams/hour)      *
 ***************************************************************************


                          TEST DATA
 ---------------------------------------------------------------------------
 !                                                                         :
 ! BURN RATE===================================>      6.30 (lb/hr-wet)       !
 ! BURN RATE===================================>      2.34 (kg/hr-dry)       !
 ! BURN RATE===================================>      2.86 (kg/hr-wet)       !
 ! FUEL MOISTURE ==============================>     18.03 (% Wet basis)     !
 ! HEAT OUTPUT=================================>  29920.14 (Btu/hr)          !
 ! FUEL HIGHER HEATING VALUE===================>   8765.00 (Btu/lb-dry)      !
 ! AVERAGE STACK FLOW RATE=====================>      8.82 (DSCF/minute w/HC)!
 ! AIR TO FUEL RATIO===========================>      7.62 (lb-air/lb-fuel)  !
 ! AVERAGE EXCESS AIR==========================>     55.73 (% Stoichiometric)!
 ! AVERAGE STACK TEMPERATURE===================>    256.70 (Degrees F)       !
 ! AVERAGE STACK MOISTURE =====================>     12.62 (% volume-wet w/HC) !
 ! AVERAGE CO2=================================>     12.28 (% volume-dry w/HC) !
 ! AVERAGE O2==================================>      7.90 (% volume-dry w/HC) !
 ! AVERAGE CO==================================>      1.07 (% volume-dry w/HC) !
 !                                                                         !
 ---------------------------------------------------------------------------

 1  ->  27                                              11:42:51
 0        67.84036                                      09-03-1987
OVERALL EFFICIENCY WITHOUT STOVE TEMPERATURE CHANGE= 66.2 %
```

FINAL

TABLE 2A
TEST DATA LISTING

```
CLIENT: ENERGY MINES AND RESOURCES CANADA
                                        RUN NUMBER: 1       DATE OF TEST: 8-13-87


PROJECT NUMBER: SE188-1                 MODEL NUMBER: KEJ-1101
FUEL MOISTURE:  22                      STACK STATIC PRESSURE(in Hg):
-3.30975E-03
BAROMETRIC PRESSURE (in Hg):  29.87     ROOM TEMPERATURE (F):  76
STOVE WEIGHT (lbs):  407                AMBIENT MOISTURE CONTENT (%):  1.9
CHANGE IN STOVE TEMPERATURE(F):  26     FUEL HHV (BTU/lb):  8765
FUEL COMPOSITION:  %C= 51      %H 7.3     %O= 41
METHOD 5 RESULTS: % MOISTURE= 12.92       GRAIN LOADING (gr/scf)= 0
```

TABLE 2B
FIELD DATA

CLIENT: ENERGY MINES AND RESOURCES CANADA

RUN NUMBER: 1 DATE: 8-13-87

			: Dry and HC free		:			
PT	TIME	WT. FUEL	%CO2	%O2	%CO	WT BLB	DRY BLB	TRACER
1	0	27.30	10.30	11.50	0.25	111.0	232.0	100.0
2	10	24.20	15.90	4.90	3.91	158.0	293.0	100.0
3	20	22.20	17.10	4.20	2.77	158.0	296.0	100.0
4	30	20.40	12.40	8.70	0.72	154.0	271.0	100.0
5	40	19.50	9.30	11.80	0.56	141.0	226.0	100.0
6	50	18.30	10.20	10.90	0.55	143.0	249.0	100.0
7	60	16.40	15.90	4.70	2.69	154.0	280.0	100.0
8	70	14.20	17.20	3.50	3.45	155.0	296.0	100.0
9	80	12.50	15.40	5.50	1.57	152.0	268.0	100.0
10	90	11.30	15.40	5.70	1.45	142.0	203.0	100.0
11	100	10.50	10.60	10.10	0.31	133.0	200.0	100.0
12	110	9.80	13.20	7.50	0.77	133.0	222.0	100.0
13	120	8.50	15.80	4.70	1.73	145.0	265.0	100.0
14	130	6.80	16.70	3.70	2.44	148.0	290.0	100.0
15	140	5.60	15.80	4.90	1.20	138.0	281.0	100.0
16	150	4.90	13.00	7.80	0.35	126.0	244.0	100.0
17	160	4.30	11.30	9.40	0.36	125.0	235.0	100.0
18	170	4.00	9.90	10.40	0.36	121.0	236.0	100.0
19	180	3.60	10.00	10.40	0.46	119.0	244.0	100.0
20	190	3.10	10.60	9.90	0.40	120.0	256.0	100.0
21	200	2.70	10.90	9.60	0.40	118.0	261.0	100.0
22	210	2.20	10.00	10.00	1.52	117.0	266.0	100.0
23	220	1.80	10.50	10.10	0.46	118.0	265.0	100.0
24	230	1.30	11.00	9.60	0.19	118.0	269.0	100.0
25	240	0.90	11.10	9.50	0.29	117.0	265.0	100.0
26	250	0.40	11.00	9.70	0.35	116.0	260.0	100.0
27	260	0.00	11.10	9.70	0.42	115.0	258.0	100.0

CO_2 Readings have been corrected due to calibrations being out of specifications — see attachment.

TABLE 3
CHO BALANCED TEST DATA

CLIENT: ENERGY MINES AND RESOURCES CANADA

RUN NUMBER: 1 DATE: 8-13-87

PT	FLOW RATE (DSCFM w/HC)	DRY BURN RATE (LB/HOUR-CALCULATED)	STACK MOISTURE (%VOLUME-w/HC)	STACK TEMP (F)
1	8.82	4.26	4.34	232.0
2	8.82	7.90	24.75	293.0
3	8.82	7.85	24.67	296.0
4	8.82	5.01	22.30	271.0
5	8.82	3.81	16.28	226.0
6	8.82	4.13	16.71	249.0
7	8.82	7.16	22.07	280.0
8	8.82	8.05	22.40	296.0
9	8.82	6.47	20.94	268.0
10	8.82	6.47	17.45	203.0
11	8.82	3.97	13.17	200.0
12	8.82	5.16	12.53	222.0
13	8.82	6.55	17.38	265.0
14	8.82	7.23	18.46	290.0
15	8.82	6.33	13.19	281.0
16	8.82	4.89	8.95	244.0
17	8.82	4.25	8.84	235.0
18	8.82	3.58	7.35	236.0
19	8.82	3.72	6.42	244.0
20	8.82	3.94	6.39	256.0
21	8.82	4.05	5.56	261.0
22	8.82	4.20	5.08	266.0
23	8.82	3.98	5.44	265.0
24	8.82	4.00	5.31	269.0
25	8.82	4.09	5.11	265.0
26	8.82	4.13	4.94	260.0
27	8.82	4.25	4.69	258.0

SE188-1

RUN#1

CO$_2$ GAS ANALYZer CALIBRATION
OUT OF SPEC.

PROBLEM :
FROM 0-70 MINUTES

CALIBRATION WENT FROM 9.9 to 9.3

SOLUTION

$$\frac{9.9-9.3}{2} = 0.3$$

→ 0.3 WILL BE ADDED TO ALL CO$_2$ READINGS IN THE OMNIFINL PROGRAM. FROM 0 to 70 MINUTES.

```
OMNI ENVIRONMENTAL SERVICES Inc.                                          PROGRAM NAME IS: REP1.EXE
CURRENT DATE/TIME IS 09-02-1987 / 19:18:38                           DATA FILE NAME IS: SE18811.DAT

-----------------------------------------------------------------------------------------------------
CLIENT: ENERGY MINES AND RESOURCES CANADA   MODEL NO. KEJ-1101
-----------------------------------------------------------------------------------------------------
PROJECT NO. SE188-01/#1                     RUN NO. #1
-----------------------------------------------------------------------------------------------------
DATE: AUG  13 1987                          TECH:  JS/DD/DC
-----------------------------------------------------------------------------------------------------
FUEL MOIST (%) 22.00                        CAT NO. OMW07
-----------------------------------------------------------------------------------------------------
FUEL CHARGE (LB) 27.3                       COAL BED (LB)  6.7
-----------------------------------------------------------------------------------------------------
TEST STARTED: AUG  13 1987 11:10:02 AM

                              ***TEST DATA (FORM 1)***

      (2)   WT   (12)  (11) RM(16) (19)  (20)  (21)  (22)  (23)  (24)   (25)  (26)  (27)  (32)   (33)
TIME  WT   DIFF  Tin   Tout  TEMP   TOP   BOT  BACK  FBOX  LEFT RIGHT BEFCAT INCAT AFTCAT FLUE  DRAFT
-----------------------------------------------------------------------------------------------------
   0 27.3  0.0   69    70    75    339   262   282   817   362   431    801   860   698   395   -.040
  10 24.2  3.1   68    70    75    332   265   297   685   343   440    852  1257   943   461   -.055
  20 22.2  2.0   70    71    77    423   270   315   632   323   421    966  1335  1137   512   -.055
  30 20.4  1.8   70    71    77    477   270   332   645   324   422    985  1253  1145   512   -.055
  40 19.5  0.9   70    71    77    471   269   320   615   319   394    789   998   917   428   -.045
  50 18.3  1.2   70    71    77    418   267   293   624   304   370    750   940   828   423   -.045
  60 16.4  1.9   70    71    77    406   262   300   750   320   387   1059  1273  1045   493   -.050
  70 14.2  2.2   70    71    77    464   258   331   800   351   435   1319  1402  1153   528   -.050
  80 12.5  1.7   67    70    77    499   254   349   832   372   454   1364  1386  1131   528   -.050
  90 11.3  1.2   59    62    76    505   252   347   823   373   445   1333  1480  1092   490   -.045
 100 10.5  0.8   58    60    74    496   250   327   746   359   420   1166  1427  1037   466   -.040
 110  9.8  0.7   67    68    75    475   248   304   747   333   391    839  1093   993   441   -.040
 120  8.5  1.3   69    70    76    446   244   297   886   354   398   1281  1318  1025   480   -.045
 130  6.8  1.7   69    71    77    474   241   326  1169   412   432   1352  1376  1129   523   -.050
 140  5.6  1.2   69    71    77    496   240   347  1228   446   460   1288  1290  1079   533   -.050
 150  4.9  0.7   58    62    76    491   242   348  1084   456   464   1088  1166   964   493   -.045
 160  4.3  0.6   60    63    75    443   244   326  1023     0   451    976  1062   870   457   -.040
 170  4.0  0.3   67    69    75    409   246   306  1119     0   435    869   960   823   431   -.040
 180  3.6  0.4   69    70    76    372   247   286  1156     0   426    867   959   791   422   -.045
 190  3.1  0.5   69    71    77    359   249   279  1183     0   427    915  1017   814   426   -.045
 200  2.7  0.4   69    71    77    359   253   279  1176    76   440    938  1005   820   427   -.045
 210  2.2  0.5   70    71    77    362   258   281  1192   271   452    945   983   814   439   -.045
 220  1.8  0.4   67    69    77    360   264   283  1162   386   458    926   987   811   435   -.045
 230  1.3  0.5   57    61    75    361   270   283   996   410   469    997  1027   807   441   -.045
 240  0.9  0.4   62    64    74    362   276   288   970   436   481    979  1003   807   445   -.045
 250  0.4  0.5   67    69    75    361   284   288   954   436   485    939   972   792   430   -.045
 260  0.0  0.4   65    69    75    361   283   287   962   436   486    932   961   784   439   -.045
-----------------------------------------------------------------------------------------------------
AVG:                         76    419   258   307   925   357   436   1019  1140   935   463   -.046

-----------------------------------------------------------------------------------------------------
AVERAGE STARTING SURFACE TEMPERATURE (F):  335            ALL TEMPERATURES IN F, WEIGHT IN LBS.
AVERAGE ENDING SURFACE TEMPERATURE   (F):  371
TEMPERATURE DIFFERENCE (Te-Ts) ........... 36

AVG. CHANNEL 5: (F)  83.1    AVG. CHANNEL 6: (F)  77.1    AVG. CHANNEL 8: (F)  42    AVG. CHANNEL 9: (F)  88.4
```

* Left thermocouple not functioning through entire test.
Avg. beginning & ending surface temperatures must be recalculated to exclude the left surface tc :

Beginning – 329 avg
Ending – 354 avg
$\Delta T_{surface}$ +26° F

OMNI

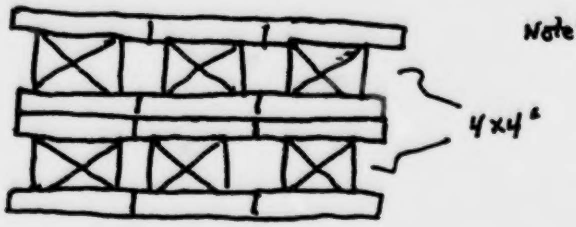
RUN NOTES — TEST

RUN # 1 CLIENT ENERGY MINES & RESOURCES CANADA PROJECT # SE188-1 MODEL King

BOOTH 1

COAL BED CHARACTERISTICS
WEIGHT AT START: 6.7 (COOL ___, GLOWING ___, FLARING ✓)

TEST FUEL CONFIGURATION SKETCH (INDICATE VIEW ANGLE)



front view

Note: Top row middle 4x4; Top rear flange removed.

START UP PROCEDURES:
BY-PASS TIME OPEN at 00 min, CLOSED at 2.00 min.
FUEL LOADING DOOR AJAR at 00 min FOR 2.00 MINUTES

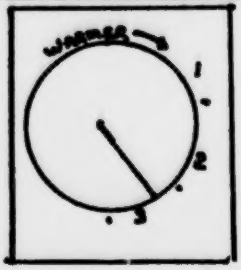
PRIMARY AIR SET Full high FOR 4.00 MINUTES
then air control ~~stov~~ slowly set to test setting

SECONDARY AIR SET fixed FOR N/A MINUTES

TERTIARY AIR SET ~~N/A~~ Fixed FOR ~~N/A~~ MINUTES - Left side of stove.

OTHER @ 5 min blower turned to high from off position at begining of test

TEST SETTINGS: (SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY AIR	SECONDARY	TERTIARY	FAN
 Primary air set at 2 5/8	fixed	~~N/A~~ fixed ⅓	High

RUN NOTES — TEST FORM 2

OMNI™

Manufacturer: ENERGY MINES & RESOURCES CANADA Run No. 1 Model No. King

Date 8.13.87 Project No. SE188-1

Date	Time	Comments
8.13.87	11:35	M-4 train clogged back FILTER, VACCUM
		WAS 15 inches. ~~END~~ STOPPED PUMP
		METER READING WAS 563.299 SW
	1144	STARTED pump METER READING 563.387 S.W.
	1230	Thermostat inspected by DO + KY (ok)
		Testing Air checked + ok
	11:50	This run is a med. High burn. we are attempting To
		simulate run # 39. SE045-1.
		We are using method 4 moisture only drawing the
		Sample at a constant rate of ΔH .6. Also
		we are using dilution tunnel method 5G
		The catylist was at 118°F 5 min 30 sec in to test

FUEL DATA

OMNI

CLIENT: ENERGY MINES & RESOURCES CANADA
PROJECT: SE188-1
BOOTH: 1

RUN #: 1
DATE: 8·13·87
FUEL LOAD PREPARED BY: JS

PRE-BURN FUEL
MOISTURE CONTENT (METER -- DRY BASIS)

CALIBRATION: Cal Value(1)=12% Actual Reading 12.50
Cal Value(2)=22% Actual Reading 21.75

Piece	Length	Readings		
1	8 ft	20.25	19.75	19.75
2	ft			
3	ft			

Length of cut pieces: 6" inches

TEST FUEL

FUEL TYPE AND AMOUNT: 2 X 4 0 4 X 4 6

CALCULATED LOAD WEIGHT: 30.1

ACTUAL LOAD WEIGHT: 0 (2 X 4)
27.3 (4 X 4)
27.3 Total

FUEL PIECE LENGTH: 17½"

MOISTURE CONTENT (METER -- DRY BASIS)

PIECE	READINGS		
1	22.25	21.50	22.50
2	23.25	23.25	23.0
3	19.75	19.75	20.50
4	22.0	22.0	21.0
5	22.0	19.50	20.50
6	24.75	24.75	24.50
7			
8			
9			
10			

OVERALL TEST FUEL LOAD MOISTURE AVERAGE: 22.00

GRAVIMETRIC ANALYSIS — OVEN-DRIED FUEL SAMPLE

DIMENSIONS: ____ X ____ X ____ = ____ cm^3

DATE/TIME SAMPLE PLACED IN OVEN: __/__/__ ____ AM PM
REMOVED: __/__/__ ____ AM PM

INITIAL WEIGHT (I) ____ - FINAL WEIGHT (F) ____ = NET WEIGHT ____

DRY BASIS MOISTURE % = $\frac{(I - F)}{F}$ X 100 = ______

DRY BASIS BY METER ______

WET BASIS MOISTURE % = $\frac{(I - F)}{F}$ X 100 = ______

TEST FUEL LOAD DENSITY = ______ gm/cm^3

OMNI ENVIRONMENTAL SERVICES Inc. PROGRAM NAME IS: REP1.EIE

CURRENT DATE/TIME IS 09-03-1987 / 12:11:11 DATA FILE NAME IS: SE18811.DAT

CLIENT: ENERGY MINES AND RESOURCES CANADA MODEL NO. KEJ-1101

PROJECT NO. SE188-01/#1 RUN NO. #1

DATE: AUG 13 1987 TECH: JS/DD/DC

FUEL MOIST (%) 22.00 CAT NO. OMW07

PRE BURN STARTED: AUG 13 1987 08:15:59 AM

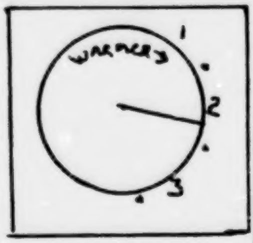
PRE BURN DATA

TIME	(2) WT	WT DIFF	(12) Tin	(11) Tout	RM(16) TEMP	(19) TOP	(20) BOT	(21) BACK	(22) FBOX	(23) LEFT	(24) RIGHT	(25) BEFCAT	(26) INCAT	(27) AFTCAT	(32) FLUE	(33) DRAFT
0	14.6	0.0	56	60	77	471	296	397	694	0	476	1518	860	809	459	-.050
10	13.4	1.2	55	58	75	430	299	364	659	0	421	879	909	856	441	-.045
20	12.4	1.0	64	66	75	423	299	349	672	211	397	1361	1065	945	438	-.045
30	11.3	1.1	67	69	77	463	294	349	679	257	390	1944	1587	1065	468	-.045
40	9.5	1.8	58	61	76	488	290	365	736	324	437	1444	1538	1055	439	-.045
50	9.0	0.5	56	60	77	471	287	323	703	338	422	954	1234	941	383	-.045
60	8.9	0.1	55	58	75	423	284	285	641	318	385	633	825	732	326	-.030
70	8.8	0.1	60	62	74	336	276	241	589	290	344	539	641	553	273	-.030
80	8.5	0.3	64	66	75	286	267	224	719	282	343	684	742	560	338	-.030
90	14.6	-6.1	65	67	73	270	262	242	492	317	361	1278	772	666	385	-.050
100	12.7	1.9	66	67	73	326	263	264	532	322	371	1683	1466	1020	458	-.050
110	11.0	1.7	66	68	73	413	264	310	647	348	429	1602	1349	1070	499	-.050
120	10.5	0.5	67	69	73	424	268	312	598	358	440	1453	1001	848	406	-.040
130	10.0	0.5	67	69	73	387	266	285	579	328	381	1044	1087	840	380	-.040
140	8.6	1.4	67	69	74	401	264	281	703	311	368	1675	1324	947	438	-.050
150	7.6	1.0	67	69	73	435	261	293	814	336	410	1764	1223	1061	465	-.045
160	7.2	0.4	68	70	74	402	260	297	834	362	437	854	914	769	410	-.040
170	6.9	0.3	68	70	74	362	262	289	822	364	436	819	870	714	389	-.040

RUN NOTES — PREBURN

RUN # 1 CLIENT ENERGY MINES & RESOURCES PROJECT # SE 188-1 MODEL King

DESCRIBE OR SKETCH AIR OR THERMOSTAT SETTINGS BELOW:
(SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY:	SECONDARY:	TERTIARY:	FAN:
	Fixed	hole left side of stove O/K.	on High

PRE-BURN SETTINGS AND ACTIVITIES

TIME	AIR (THERMO) CHANGES PRIMARY SECDRY TERTRY	FAN SETTNG CHANGE	ADD FUEL +WT.	REMOVE FUEL -WT.	RAKE COAL	COMMENT
@30					*	
@35	Primary air setting changed from $1\frac{3}{4}$ to $2\frac{1}{4}$.					
@90				*		1.5
@95	Also Primary air setting changed from $2\frac{1}{4}$ to $2\frac{1}{2}$		*			8.2
@135	Primary air setting changed from $2\frac{1}{2}$ to $2\frac{5}{8}$				*	

```
                              TABLE 1

-------------------------------------------------------------------------------

RESULTS OF EFFICIENCY TESTING ON THE ENERGY MINES AND RESOURCES CANADA
 WOOD STOVE

RUN NUMBER 2   PROJECT NUMBER SE188-1  SERIAL NUMBER C1106

DATE OF TEST: 8-19-87          STOVE MODEL: KEJ                FINAL

-------------------------------------------------------------------------------


                       AVERAGE EFFICIENCIES

*******************************************************************************
* COMBUSTION= 84.1   % * HEAT TRANS.= 83.3   % * OVERALL= 70.1   %
 *
*******************************************************************************

                             EMISSIONS

*******************************************************************************
* PARTICULATES:       0.000  (grams/Kg-wood)     0.000  (grams/hour)          *
* CARBON MONOXIDE:   57.940  (grams/Kg-wood)    90.106  (grams/hour)          *
*******************************************************************************


                             TEST DATA
-------------------------------------------------------------------------------
:                                                                             :
: BURN RATE==================================>      4.20 (lb/hr-wet)          :
: BURN RATE==================================>      1.56 (kg/hr-dry)          :
: BURN RATE==================================>      1.91 (kg/hr-wet)          :
: FUEL MOISTURE =============================>     18.37 (% Wet basis)        :
: HEAT OUTPUT================================>  21056.53 (Btu/hr)             :
: FUEL HIGHER HEATING VALUE==================>   8765.00 (Btu/lb-dry)         :
: AVERAGE STACK FLOW RATE====================>      7.47 (DSCF/minute w/HC)   :
: AIR TO FUEL RATIO==========================>      9.85 (lb-air/lb-fuel)     :
: AVERAGE EXCESS AIR=========================>     92.60 (% Stoichiometric)   :
: AVERAGE STACK TEMPERATURE==================>    210.26 (Degrees F)          :
: AVERAGE STACK MOISTURE ====================>     10.09 (% volume-wet w/HC)  :
: AVERAGE CO2================================>     10.09 (% volume-dry w/HC)  :
: AVERAGE O2=================================>     10.25 (% volume-dry w/HC)  :
: AVERAGE CO=================================>      0.61 (% volume-dry w/HC)  :
:                                                                             :
-------------------------------------------------------------------------------

1  ->  42                                                  11:47:37
0        71.10446                                          09-03-1987
OVERALL EFFICIENCY WITHOUT STOVE TEMPERATURE CHANGE= 70.1 %
```

TABLE 2A
TEST DATA LISTING

CLIENT: ENERGY MINES AND RESOURCES CANADA
RUN NUMBER: 2 DATE OF TEST: 8-19-8

PROJECT NUMBER: SE188-1 MODEL NUMBER: KEJ
FUEL MOISTURE: 22.5 STACK STATIC PRESSURE(in Hg):
-2.57425E-03
BAROMETRIC PRESSURE (in Hg): 29.92 ROOM TEMPERATURE (F): 75
STOVE WEIGHT (lbs): 407 AMBIENT MOISTURE CONTENT (%): 1.4
CHANGE IN STOVE TEMPERATURE(F): 2 FUEL HHV (BTU/lb): 8765
FUEL COMPOSITION: %C= 51 %H 7.3 %O= 41
METHOD 5 RESULTS: % MOISTURE= 10.26 GRAIN LOADING (gr/scf)= 0

TABLE 2B
FIELD DATA

CLIENT: ENERGY MINES AND RESOURCES CANADA

RUN NUMBER: 2 DATE: 8-19-87

			Dry and HC free					
PT	TIME	WT. FUEL	%CO2	%O2	%CO	WT BLB	DRY BLB	TRACER
1	0	28.70	6.70	13.80	0.21	109.0	182.0	100.0
2	10	27.50	6.40	14.00	0.32	125.0	202.0	100.0
3	20	26.80	6.80	13.70	0.72	130.0	198.0	100.0
4	30	25.70	9.20	11.50	0.95	130.0	212.0	100.0
5	40	24.40	9.20	11.70	0.64	138.0	227.0	100.0
6	50	23.20	8.70	12.30	0.63	138.0	239.0	100.0
7	60	22.00	8.40	12.60	0.64	134.0	242.0	100.0
8	70	20.90	9.10	11.70	0.87	136.0	241.0	100.0
9	80	19.70	10.70	10.50	1.03	140.0	252.0	100.0
10	90	18.30	12.10	9.00	1.02	131.0	261.0	100.0
11	100	16.90	13.00	8.20	1.12	137.0	271.0	100.0
12	110	15.60	14.00	7.20	1.12	140.0	265.0	100.0
13	120	14.60	11.10	10.00	0.44	139.0	226.0	100.0
14	130	13.90	9.50	11.30	0.58	131.0	206.0	100.0
15	140	13.30	9.40	11.50	0.52	123.0	200.0	100.0
16	150	12.40	13.60	7.60	0.92	132.0	239.0	100.0
17	160	10.90	16.80	3.80	2.59	144.0	272.0	100.0
18	170	9.30	16.70	3.90	3.35	145.0	248.0	100.0
19	180	8.50	12.80	8.50	0.32	132.0	206.0	100.0
20	190	8.10	8.90	11.80	0.30	122.0	187.0	100.0
21	200	7.70	8.80	12.00	0.30	120.0	174.0	100.0
22	210	7.30	11.10	9.70	0.58	121.0	189.0	100.0
23	220	6.70	12.00	8.80	0.50	122.0	216.0	100.0
24	230	5.80	13.60	7.00	0.51	126.0	231.0	100.0
25	240	4.90	14.30	6.60	0.58	127.0	236.0	100.0
26	250	4.30	11.90	9.20	0.32	119.0	203.0	100.0
27	260	4.10	7.80	12.80	0.05	109.0	169.0	100.0
28	270	3.90	7.80	12.80	0.17	108.0	159.0	100.0
29	280	3.80	6.60	13.40	0.15	97.0	155.0	100.0
30	290	3.50	10.30	10.60	0.38	100.0	179.0	100.0
31	300	3.10	11.30	9.30	0.46	110.0	196.0	100.0
32	310	2.60	11.10	8.80	0.37	117.0	212.0	100.0
33	320	2.30	10.60	9.80	0.31	111.0	213.0	100.0
34	330	2.00	9.90	10.70	0.30	106.0	203.0	100.0
35	340	1.70	9.10	11.30	0.30	103.0	188.0	100.0
36	350	1.50	8.70	11.80	0.30	100.0	180.0	100.0
37	360	1.30	8.50	12.00	0.34	98.0	178.0	100.0
38	370	1.10	8.80	11.70	0.44	98.0	182.0	100.0
39	380	0.90	9.40	11.10	0.47	100.0	194.0	100.0
40	390	0.60	9.50	11.10	0.49	101.0	198.0	100.0
41	400	0.30	9.70	11.00	0.42	103.0	201.0	100.0
42	410	0.00	9.00	11.50	0.37	103.0	199.0	100.0

TABLE 3
CHO BALANCED TEST DATA

CLIENT: ENERGY MINES AND RESOURCES CANADA

RUN NUMBER: 2 DATE: 6-19-87

PT	FLOW RATE (DSCFM w/HC)	DRY BURN RATE (LB/HOUR-CALCULATED)	STACK MOISTURE (%VOLUME-w/HC)	STACK TEMP (F)
1	7.47	2.04	6.18	182.0
2	7.47	1.97	11.32	202.0
3	7.47	2.34	13.75	198.0
4	7.47	3.26	13.27	212.0
5	7.47	3.17	16.96	227.0
6	7.47	3.05	16.56	239.0
7	7.47	2.96	14.27	242.0
8	7.47	3.22	15.38	241.0
9	7.47	3.92	17.30	252.0
10	7.47	4.30	12.09	261.0
11	7.47	4.64	14.94	271.0
12	7.47	4.94	16.88	265.0
13	7.47	3.71	17.56	226.0
14	7.47	3.20	13.96	206.0
15	7.47	3.17	10.54	200.0
16	7.47	4.72	13.34	239.0
17	7.47	6.28	19.13	272.0
18	7.47	6.60	20.53	248.0
19	7.47	4.22	14.45	206.0
20	7.47	2.83	10.59	187.0
21	7.47	2.84	10.26	174.0
22	7.47	3.68	10.12	189.0
23	7.47	3.91	9.57	216.0
24	7.47	4.33	10.75	231.0
25	7.47	4.67	11.03	236.0
26	7.47	3.89	8.84	203.0
27	7.47	2.33	6.66	169.0
28	7.47	2.40	6.73	159.0
29	7.47	1.80	4.02	155.0
30	7.47	3.37	3.83	179.0
31	7.47	3.61	5.98	196.0
32	7.47	3.26	7.77	212.0
33	7.47	3.25	5.68	213.0
34	7.47	3.10	4.53	203.0
35	7.47	2.79	4.26	188.0
36	7.47	2.70	3.80	180.0
37	7.47	2.66	3.39	178.0
38	7.47	2.81	3.24	182.0
39	7.47	3.00	3.28	194.0
40	7.47	3.08	3.38	198.0
41	7.47	3.14	3.78	201.0
42	7.47	2.83	3.86	199.0

```
                    EPA METHOD 5G RESULTS

             CLIENT ENERGY MINES AND RESOURCES CANADA
              MODEL KEJ-1101
          PROJECT # SE188-1
               RUN# 2
               DATE 8-19-87
      FILTER HOLDER B

                    EPA METHOD 5G RESULTS


*****************************************************************
PARTICULATE CONCENTRATION (DRY-STANDARD)..  0.0010 (GRAMS/DSCF)
PARTICULATE EMISSION RATE.................   8.592 (GRAMS/HOUR)
ADJUSTED EMISSIONS........................    10.8 (GRAMS/HOUR)
*****************************************************************

TUNNEL TEMPERATURE AVERAGE................      90 (DEGREES FAHRENHEIT)

AVERAGE DELTA P RUN DATA..................   0.036 (INCHES H20)

(Vm)TOTAL SAMPLE VOLUME (METER CONDITIONS) 210.881 (CUBIC FEET)
AVERAGE GAS METER TEMPERATURE.............      86 (DEGREES FAHRENHEIT)
(vs)AVG. GAS VELOCITY IN DILUTION TUNNEL..   12.80 (FEET/SECOND)
(Qsd)AVG. GAS FLOW RATE IN DILUTION TUNNEL 8316.49 (DSCFH)
(Vmstd)TOTAL SAMPLE VOL. (STD. CONDITIONS) 201.906 (DSCF)
-----------------------------------------------------------------

(mn) TOTAL PARTICULATES...................   208.6 (MG)
AVERAGE DELTA H...........................    0.55 (INCHES H20)
TOTAL TIME OF TEST........................     410 (MINUTES)
```

FINAL

```
OMNI ENVIRONMENTAL SERVICES Inc.                                        PROGRAM NAME IS: REP1.EXE
CURRENT DATE/TIME IS 09-02-1987 / 19:22:17                              DATA FILE NAME IS: SE18812.DAT

-------------------------------------------------------------------------------------------------
CLIENT: ENERGY MINES RESOURCES CANADA                  MODEL NO. KEJ-1101
-------------------------------------------------------------------------------------------------
PROJECT NO. SE188-01/2                                 RUN NO. 2
-------------------------------------------------------------------------------------------------
DATE: AUG  19 1987                                     TECH:
-------------------------------------------------------------------------------------------------
FUEL MOIST (%) 22.50                                   CAT NO. OMW11
-------------------------------------------------------------------------------------------------
FUEL CHARGE (LB) 28.7                                  COAL BED (LB)   6.5
-------------------------------------------------------------------------------------------------
TEST STARTED: AUG  19 1987 09:02:53 AM

                                  ***TEST DATA (FORM 1)***

       (2)    WT   (12)   (11)  RM(16)  (19)   (20)   (21)   (22)    (23)   (24)   (25)   (26)   (27)   (32)   (33)
TIME   WT   DIFF   Tin    Tout   TEMP   TOP    BOT    BACK   FBOX*   LEFT  RIGHT BEFCAT  INCAT AFTCAT  FLUE   DRAFT
-------------------------------------------------------------------------------------------------------------------
   0  28.7   0.0    57     60     74    405    251    224      0     319    311    696   1131    839    374   -.030
  10  27.5   1.2    67     68     74    310    249    205      0     285    307    567    783    634    352   -.035
  20  26.8   0.7    68     69     75    271    244    193      0     261    288    532    761    604    333   -.035
  30  25.7   1.1    68     69     75    249    240    184      0     260    305    613    942    688    338   -.035
  40  24.4   1.3    68     69     75    261    237    184      0     272    338    678   1013    769    370   -.040
  50  23.2   1.2    68     69     76    286    235    193      0     282    347    710   1037    790    390   -.040
  60  22.0   1.2    69     70     76    310    232    203      0     287    347    685   1052    807    413   -.040
  70  20.9   1.1    69     70     77    324    229    205      0     282    340    658   1029    806    409   -.040
  80  19.7   1.2    63     66     76    340    228    206      0     282    343    675   1080    848    424   -.045
  90  18.3   1.4    63     65     74    368    229    212      0     287    368    775   1161    913    442   -.045
 100  16.9   1.4    67     69     75    396    232    223      0     301    413    865   1277    974    466   -.040
 110  15.6   1.3    69     70     76    417    235    234      0     315    442    904   1480   1067    493   -.045
 120  14.6   1.0    66     69     77    442    237    241      0     313    400    900   1481   1040    440   -.040
 130  13.9   0.7    58     60     74    424    239    230      0     301    366    806   1360    922    432   -.040
 140  13.3   0.6    66     67     75    391    241    217      0     290    344    779   1308    859    396   -.035
 150  12.4   0.9    68     69     75    368    243    210      0     290    339    926   1396    909    417   -.040
 160  10.9   1.5    68     70     76    401    246    223      0     313    402   1368   1583   1099    481   -.045
 170   9.3   1.6    69     71     77    448    248    245      0     350    470   1392   1566   1098    501   -.045
 180   8.5   0.8    60     63     76    445    250    247      0     351    443   1353   1498   1000    454   -.040
 190   8.1   0.4    62     64     74    419    248    234      0     329    397    849   1335    874    399   -.035
 200   7.7   0.4    66     68     74    386    246    219      0     313    375    749   1218    790    363   -.030
 210   7.3   0.4    68     69     76    357    241    205      0     297    358    761   1280    844    385   -.030
 220   6.7   0.6    68     69     76    342    237    199      0     304    381    737   1014    772    392   -.030
 230   5.8   0.9    68     70     76    330    233    204      0     330    424    921   1223    848    414   -.035
 240   4.9   0.9    69     70     76    356    232    221      0     360    465    969   1299    931    452   -.035
 250   4.3   0.6    70     71     77    373    235    229      0     370    466    905   1204    867    425   -.030
 260   4.1   0.2    60     63     76    352    238    222      0     347    417    785   1076    718    326   -.030
 270   3.9   0.2    62     63     74    321    239    209      0     326    374    715   1038    661    333   -.025
 280   3.8   0.1    66     68     74    293    238    193      0     306    343    624    878    590    303   -.025
 290   3.5   0.3    67     69     75    271    234    183      0     298    337    663    875    624    332   -.020
 300   3.1   0.4    67     69     75    266    230    182      0     315    360    736    892    658    345   -.020
 310   2.6   0.5    68     69     75    272    231    191      0     368    378    831    908    683    375   -.020
 320   2.3   0.3    69     71     77    284    238    209      0     416    388    831    931    694    384   -.020
 330   2.0   0.3    60     63     77    290    246    219      0     424    387    796    910    679    361   -.030
 340   1.7   0.3    59     61     75    288    253    219     10     417    375    757    892    656    348   -.030
 350   1.5   0.2    67     69     76    281    260    214      0     407    359    713    876    632    344   -.030
 360   1.3   0.2    62     65     77    274    264    210      0     397    347    691    870    622    333   -.025
 370   1.1   0.2    61     63     74    267    263    198      0     385    337    686    873    628    343   -.025
 380   0.9   0.2    67     68     75    267    265    198    703     385    337    703    865    633    349   -.025
 390   0.6   0.3    69     70     77    268    267    200      0     391    342    717    877    641    355   -.025
 400   0.3   0.3    58     61     75    271    269    202      0     395    348    727    866    646    357   -.030
 410   0.0   0.3    62     61     76    277    275    209      3     399    363    724    827    629    360   -.030
-------------------------------------------------------------------------------------------------------------------
AVG:                              75    332    243    211    239     331    371    797   1094    785    388   -.033

-------------------------------------------------------------------------------------------------------------------
AVERAGE STARTING SURFACE TEMPERATURE (F):  302                      ALL TEMPERATURES IN F, WEIGHT IN LBS.
AVERAGE ENDING SURFACE TEMPERATURE   (F):  304
TEMPERATURE DIFFERENCE (Te-Ts) ........... 2

AVG. CHANNEL 5: (F)  86.4     AVG. CHANNEL 6: (F)  84.6     AVG. CHANNEL 8: (F)  74.3     AVG. CHANNEL 9: (F)  90.3
```

*T.C. Malfunction

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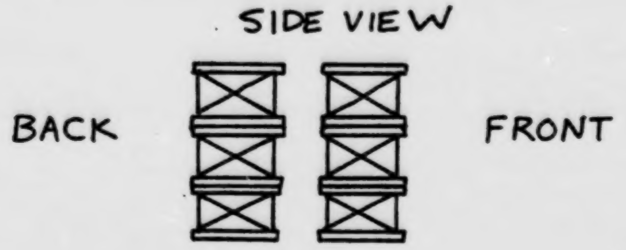
RUN NOTES — TEST

RUN # 2 CLIENT E.M.R. Canada PROJECT # SE188-1 MODEL KEJ

BOOTH 1

COAL BED CHARACTERISTICS
WEIGHT AT START: 6.5 (COOL ___, GLOWING ✓, FLARING ___)

TEST FUEL CONFIGURATION SKETCH (INDICATE VIEW ANGLE)



START UP PROCEDURES:
BY-PASS TIME OPEN ✓, CLOSED @1min.
FUEL LOADING DOOR AJAR To load FOR 1 MINUTES

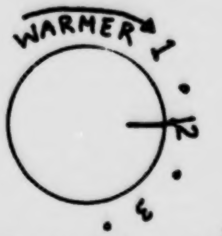
PRIMARY AIR SET Full High FOR 4 MINUTES
at 4 minutes we shut down the air
control slowly to the Test setting. set at 4min 20 sec.

SECONDARY AIR SET FIXED FOR N.A. MINUTES

TERTIARY AIR SET N.A. FOR N.A. MINUTES

OTHER Catalyst temp at 827°F at 5 min.

TEST SETTINGS: (SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY AIR	SECONDARY	TERTIARY	FAN
 (set slightly under the #2 setting)	FIXED	N.A.	High

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RUN NOTES — TEST FORM 2

Manufacturer E.M.R. Run No. 2 Model No. KEJ

Date 8-19-87 Project No. SE188-1

Date	Time	Comments
8-19-87	1940	I am preparing a test run with "5G" and "M-4" sampling equipment. The test run is set slightly above the #2 position on the thermostatic control. The client (Keith Yowood) will be present for the start-up of the test. The Method-4 sample train will be sampling at a constant ΔH of .60 S.D.
8-19-87	1952	Raked the coals during the preburn. At 52 min. I raked the coals away from the primary air inlet because the coals were blocking the air inlet resulting in a slower burn rate. S.D.
8-19-87	2114	The test got a cooler start than we would have liked but the catalyst did take off and sure we were burning. The "Co" was a little high at first. S.D.

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RUN NOTES — TEST FORM 2

Manufacturer EMR Canada . Run No. 2 Model No. KING

Date 8/20/87 Project No. SE188-01

Date	Time	Comments CATALYST # W-11
8/20	0900	130TH – 150TH GAP ON TOP OF BUTT JOINT
		GAP TAPERS down TOWARDS THE
		BOTTOM OF JOINT TO APPROX 85 – 90TH.
		WHERE THE SEAL RIM STARTS.
		WITH A FLOOD LIGHT UNDERNEATH
		CATALYST A SMALL PIN HOLE RAY OF
		LIGHT could be SEEN WHEN
		LOOKING FROM TOP OF CATALYST.
		CATALYST HAS BEEN CHIPPED ON
		ONE TOP CELL WHERE THE
		TC PROBE WAS INSERTED.
		CHIP IS APPROX ½ THE DEPTH
		OF THE CELL.
		ANOTHER CHIP IS NOTED ON
		THE bottom SIDE OF CATALYST
		ON THE NEXT CELL OVER FROM
		THE TOPSIDE CHIP. TO A DEPTH
		OF APPROX ½ THE CELL SIZE.

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FUEL DATA

CLIENT: EMR
PROJECT: SE188-1
BOOTH: 1

RUN #: 2
DATE: SD

PRE-BURN FUEL

MOISTURE CONTENT (METER — DRY BASIS)

CALIBRATION: Cal Value(1)=12% Actual Reading 12.3 %
Cal Value(2)=22% Actual Reading 22.0 %

Piece	**Length**	**Readings**		
1	8 ft	23.5	23.25	23.75
2	ft			
3	ft			

Length of cut pieces: 5 inches

TEST FUEL

FUEL TYPE AND AMOUNT: 2 × 4 0 4 × 4 6

CALCULATED LOAD WEIGHT: 30.1 ACTUAL LOAD WEIGHT: 0 (2 × 4)
28.7 (4 × 4)
28.7 Total

FUEL PIECE LENGTH: 17.5"

MOISTURE CONTENT (METER — DRY BASIS)

PIECE	**READINGS**		
1	22.25	22.0	22.75
2	21.25	22.25	23.0
3	21.5	22.75	22.75
4	23.75	23.25	23.5
5	21.5	21.5	21.0
6	23.25	23.5	23.75
7			
8			
9			
10			

OVERALL TEST FUEL LOAD MOISTURE AVERAGE: 22.53

GRAVIMETRIC ANALYSIS — OVEN-DRIED FUEL SAMPLE

DIMENSIONS: ______ × ______ × ______ = ______ cm^3
DATE/TIME SAMPLE PLACED IN OVEN: __/__/__ ______ AM PM
REMOVED: __/__/__ ______ AM PM
INITIAL WEIGHT (I) ____ - FINAL WEIGHT (F) ____ = NET WEIGHT ____

DRY BASIS MOISTURE % = $\frac{(I - F)}{F}$ × 100 = ______
DRY BASIS BY METER ______

WET BASIS MOISTURE % = $\frac{(I - F)}{F}$ × 100 = ______

TEST FUEL LOAD DENSITY = ______ gm/cm^3

```
OMNI ENVIRONMENTAL SERVICES Inc.                                          PROGRAM NAME IS: REP1.EXE
CURRENT DATE/TIME IS 09-03-1987 / 12:09:12                                DATA FILE NAME IS: SE18812.DAT

-----------------------------------------------------------------------------------------------------
CLIENT: ENERGY MINES AND RESOURCES CANADA              MODEL NO. KEJ-1101
-----------------------------------------------------------------------------------------------------
PROJECT NO. SE188-01/2                                 RUN NO. 2
-----------------------------------------------------------------------------------------------------
DATE: AUG  19 1987                                     TECH:
-----------------------------------------------------------------------------------------------------
FUEL MOIST (%) 22.5                                    CAT NO. OMW11
-----------------------------------------------------------------------------------------------------
PRE BURN STARTED: AUG  19 1987 07:09:16 AM

                                    ***PRE BURN DATA***

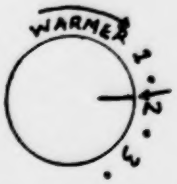
      (2)     WT   (12)   (11) RM(16)  (19)  (20)  (21)  (22)  (23)  (24)   (25)  (26)   (27)  (32)   (33)
TIME   WT   DIFF   Tin   Tout   TEMP   TOP   BOT  BACK  FBOX  LEFT RIGHT BEFCAT INCAT AFTCAT  FLUE  DRAFT
-----------------------------------------------------------------------------------------------------------
   0  15.1   0.0    69     70     78   468   186   353  1190   505   485      0  1301   1040   677  -.045
  10  14.1   1.0    60     64     77   466   202   328  1048   457   434      0  1494   1042   510  -.030
  20  13.5   0.6    57     61     75   414   219   279   646   387   359      0   961    753   418  -.035
  30  12.1   1.4    67     68     76   346   226   255   598   363   337      0  1003    717   412  -.045
  40  11.5   0.6    69     70     77   329   230   236   663   346   316      0  1189    794   394  -.035
  50  10.9   0.6    61     64     76   324   233   221   626   327   297      0  1061    727   353  -.030
  60  10.3   0.6    62     63     74   313   234   214   683   328   294      0  1161    737   362  -.030
  70   9.4   0.9    67     68     75   315   236   214   583   321   291      0   919    717   380  -.035
  80   8.5   0.9    68     70     76   344   240   215  1284   321   296      0  1654    991   390  -.035
  90   7.8   0.7    69     70     76   385   244   220  1336   324   306      0  1503    961   401  -.030
 100   7.1   0.7    69     71     77   389   247   221   671   318   306      0  1080    849   607  -.040
 110   6.4   0.7    57     60     74   405   251   224   696   319   311      0  1131    839   374  -.030
```

OMNI™

RUN NOTES — PREBURN

RUN # 2 CLIENT E.M.R. PROJECT # SE188-1 MODEL KEJ

DESCRIBE OR SKETCH AIR OR THERMOSTAT SETTINGS BELOW:
(SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY:	SECONDARY:	TERTIARY:	FAN:
 (Set slightly under the # 2 mark.)	Fixed	N.A.	High

PRE-BURN SETTINGS AND ACTIVITIES

TIME	AIR (THERMO) CHANGES			FAN SETTING CHANGE	ADD FUEL +WT.	REMOVE FUEL -WT.	RAKE COAL	COMMENT
	PRIMARY	SECDRY	TERTRY					
@26							✓	
@52							✓	
@67							✓	
@75							✓	
@98							✓	

TEST DATA REPORT

Woodcutter's Manufacturing

Blaze King

Prepared for: Woodcutter's Mfg.
Route 4, 3301 E. Isaacs
Walla Walla, WA 99362

Prepared by: OMNI Environmental Services, Inc.
10950 SW Fifth Street, Suite 160
Beaverton, OR 97005

August 25, 1987

SE045-10

SUMMARY

Woodcutter's Mfg. retained OMNI Environmental Services, Inc., to perform emissions and efficiency testing on the Blaze King "King" woodstove. This appliance was tested in accordance with the Oregon Department of Environmental Quality (DEQ) "Standard Method for Measuring the Emissions and Efficiency of Woodstoves," dated June 8, 1984, and the Environmental Protection Agency (EPA) 40 CFR Part 60, Subpart AAA — Standard of Performance for Residential Wood Heaters, as published for comment on Wednesday, February 19, 1987. Emissions were measured using the EPA Method 5G. The testing was performed August 14, 21, 24, and 25, 1987, at the OMNI Solid Fuels Testing Laboratory in Beaverton, Oregon.

Four test runs were completed, and efficiencies and particulate emissions were measured. Heat outputs for runs 2, 3, 4, and 6 were 14062, 17836, 34802, and 10890 Btus per hour. Overall efficiencies were 68.1, 66.9, 63.9, and 61.9 percent, respectively. From EPA Method 5G, particulate emissions were measured to be 11.8, 9.4, 16.6, and 18.6 grams per hour, respectively.

Primary air settings used for the test runs and the five minute start-up procedure for each run are as shown below:

Run #	Air Control Lever Setting	Five-Minute Start-Up Procedure
2	Low	Door: ajar for 1 minute. Bypass: open for 1 minute. Primary Air: full high for 4 minutes, then set to test setting. Fan: off for 5 minutes, then set to high for test.
3	1 $^{3}/_{4}$	Door: ajar for 1.5 minutes. Bypass: sealed closed. Primary Air: full high for 4.5 minutes, then set to test setting. Fan: high for test.
4	Full High	Door: ajar for 2 minutes. Bypass: closed for test. Primary Air: full high for test. Fan: high for test.
6	1.25	Door: ajar for 2 minutes. Bypass: closed for test. Primary Air: full high for 4.75 minutes, then set to test setting. Fan: high for test.

Catalyst Description:

Manufacturer:	Matsushita Battery
Distributor:	Technical Glass Products
Model:	86-04
Field No.:	W07
Size:	oval, maximum dimensions $7^1/_8$ x $8^5/_8$, 2" thickness
Cells/in^2:	16

Aging time, field source: Whitehorse project

Six test runs were attempted using the OMW07 combustor that was retrieved from home W07 in Whitehorse, Canada. This combustor is a Matsushita product distributed by Technical Glass Products and canned by Woodcutter's Manufacturing of Canada specifically for Canadian-manufactured Blaze King "King" woodstoves. Test runs 1 and 5 were terminated shortly after the test started due to poor starts as a result of relatively cool coalbeds and stove surface temperatures.

Run 1 was considered a poor start because the temperature downstream of the combustor decreased from 524° F to 282° F by 40 minutes. This occurred even though the temperature within the combustor was 880° F after the five minute startup period. In conjunction with this the stack gas oxygen levels rose from 14.7 percent to 17.6 percent indicating that the fire was going out.

Run 5 was considered a poor start because the temperature within the combustor was only 438° F after the five minute startup. Like run 1, the oxygen levels were increasing, and the combustor temperatures were decreasing, indicating that the fire was not ignited well enough to sustain a burn throughout the test. In addition, the average stove surface temperatures at the beginning of the test were well below the average stove surface temperatures of the original certification test at a similar heat output.

Test runs 1 and 2 were conducted with the combustor and bypass in the same configuration as the previous EMR test. The combustor and the bypass damper door were inspected for leaks before and after the runs using a 500-watt light. The inspections showed no light leakage around the combustor or the bypass. After run 2, the combustor was removed so that other testing could be conducted.

Prior to run 3, the bypass was sealed tight with stove cement to ensure that no gas leakage would occur. The combustor was reinstalled using two wraps of interam provided by Woodcutter's. After burning the unit for 2 hours, the combustor and bypass were inspected for leakage using the 500-watt light. There was no leakage observed around the bypass. However, there was leakage observed around the combustor. Further inspection revealed that the interam had not uniformly expanded, creating gaps through which light could leak. The combustor was removed and reinstalled with one wrap of new interam that overlapped itself. After burning the unit for two hours and performing a light leak test, no leaks were observed. Test runs 3, 4, 5, and 6 were then conducted. Before and after each test run, the bypass and combustor were inspected for light leaks. Light leakage was not observed during any of these inspections.

It should be noted that each inspection was conducted using a 500-watt light placed in the firebox. The combustor and bypass were then inspected by darkening the room and looking down through the flue collar. From this view it was possible to inspect all of the bypass damper door seals and the back and side edges of the combustor. It was impossible to inspect the front edge of the combustor. Combustion gas leaks were considered to be present if light could be observed through the areas in which the bypass or combustor make contact with their respective seals in the stove.

Summary Tables, reduced data results, and calorimeter room raw data sheets are included for each run.

SUMMARY TABLE 1

Woodcutter's Mfg. Blaze King "King"

Project SE045-10

RESULTS

RUN #	PARTICULATE EMISSION GM/HR	HEAT OUTPUT**	OVERALL EFFICIENCY*	COMBUSTION % EFFICIENCY	HEAT TRANSFER % EFFICIENCY
2	11.8	14062	68.1	82.5	82.6
3	9.4	17836	66.9	84.3	79.4
4	16.6	34802	63.9	79.0	80.8
6	18.6	10890	61.9	75.2	82.3

Oregon Weighted particulate emission over 4 test runs (2, 3, 4, and 6): 14.6 grams per hour.
Oregon Weighted overall efficiency: 64.9%.

*** Corrected for stove thermal mass**

**** Btu per hour**

SUMMARY TABLE 2

Woodcutter's Mfg. Blaze King "King"

Project SE045-10

FUEL AND OPERATING PARAMETERS

RUN #	BURN RATE KG/HR (DRY)	FUEL H_2O %(WET) TEST LOAD	HHV*	TIME (MIN)	POUNDS BURNED
2	1.07	17.86	8765	630	30.1
3	1.38	17.53	8765	490	30.1
4	2.82	16.67	8765	230	28.6
6	0.91	16.67	8765	730	29.3

* Higher heating value (Btu/lb) (assumed value used)

SUMMARY TABLE 3

Woodcutter's Mfg. Blaze King "King"

Project SE045-10

CARBON MONOXIDE EMISSIONS

RUN #	GRAMS CO/KG	GRAMS CO/HOUR
2	86.83	92.73
3	72.51	99.97
4	106.40	300.08
6	207.90	189.24

SUMMARY TABLE 4

Woodcutter's Mfg. Blaze King "King"

Project SE045-10

FLUE GAS MEASUREMENTS

RUN #	TEMP °F	H_2O%	O_2%	CO_2%	CO%	EXCESS AIR %	FLOW RATE CHO DSCF/MIN	DRAFT IN. H_2O	AIR/FUEL RATIO LB/LB
2	172	8.37	12.23	8.07	0.76	133.13	6.20	-.025	11.95
3	200	10.14	12.23	8.08	0.61	132.63	8.24	-.030	12.35
4	29~~6~~3	12.13	7.55	12.48	1.52	47.23	9.97	-.045	7.09
6	132	8.88	14.05	5.86	1.55	184.63	6.18	-.015	13.92

SUMMARY TABLE 5

Woodcutter's Mfg. Blaze King "King"

Project SE045-10

AVERAGE STOVE TEMPERATURES OVER TEST CYCLE *

	STOVE SURFACE						COMBUSTOR		
RUN #	TOP	BOTTOM	LEFT	RIGHT	BACK	FIREBOX	UPSTREAM	WITHIN	DOWNSTREAM
2	274	192	253	313	189	508	555	827	627
3	356	263	343	363	204	N/A	N/A	1035	709
4	489	335	488	499	279	N/A	1088	1256	N/A
6	220	197	238	257	141	N/A	441	682	N/A

* All temperatures in degrees Fahrenheit

FINAL

```
                    EPA METHOD 5G RESULTS


                  CLIENT WOODCUTTERS
                   MODEL KING
               PROJECT # SE045-10
                    RUN# 2
                    DATE 8-14-87
           FILTER HOLDER B


                    EPA METHOD 5G RESULTS



*************************************************************************
PARTICULATE CONCENTRATION (DRY-STANDARD)..  0.0011 (GRAMS/DSCF)
PARTICULATE EMISSION RATE.................   9.478 (GRAMS/HOUR)
ADJUSTED EMISSIONS........................    11.8 (GRAMS/HOUR)
*************************************************************************

TUNNEL TEMPERATURE AVERAGE................      81 (DEGREES FAHRENHEIT)

AVERAGE DELTA P RUN DATA..................   0.038 (INCHES H20)

(Vm)TOTAL SAMPLE VOLUME (METER CONDITIONS) 324.224 (CUBIC FEET)
AVERAGE GAS METER TEMPERATURE.............      87 (DEGREES FAHRENHEIT)
(vs)AVG. GAS VELOCITY IN DILUTION TUNNEL..   13.06 (FEET/SECOND)
(Qsd)AVG. GAS FLOW RATE IN DILUTION TUNNEL 8605.43 (DSCFH)
(Vmstd)TOTAL SAMPLE VOL. (STD. CONDITIONS) 309.504 (DSCF)
-------------------------------------------------------------------------

(mn) TOTAL PARTICULATES...................   340.9 (MG)
AVERAGE DELTA H...........................    0.55 (INCHES H20)
TOTAL TIME OF TEST........................     630 (MINUTES)
```

FINAL

```
                          TABLE 1
-------------------------------------------------------------------------
RESULTS OF EFFICIENCY TESTING ON THE WOODCUTTERS WOOD STOVE

RUN NUMBER 2   PROJECT NUMBER SE045-10  SERIAL NUMBER C1106

DATE OF TEST: 8-14-87          STOVE MODEL: KING

-------------------------------------------------------------------------


                    AVERAGE EFFICIENCIES

*************************************************************************
* COMBUSTION= 82.5   % *  HEAT TRANS.= 82.6   % *  OVERALL= 68.1    % *
*************************************************************************

                         EMISSIONS

*************************************************************************
* PARTICULATES:        0.000  (grams/Kg-wood)     0.000  (grams/hour)   *
* CARBON MONOXIDE:   86.827  (grams/Kg-wood)    92.731  (grams/hour)    *
*************************************************************************


                         TEST DATA
-------------------------------------------------------------------------
:                                                                       :
: BURN RATE===============================>       2.87 (lb/hr-wet)      :
: BURN RATE===============================>       1.07 (kg/hr-dry)      :
: BURN RATE===============================>       1.30 (kg/hr-wet)      :
: FUEL MOISTURE ==========================>      17.86 (% Wet basis)    :
: HEAT OUTPUT=============================>   14062.14 (Btu/hr)         :
: FUEL HIGHER HEATING VALUE===============>    8765.00 (Btu/lb-dry)     :
: AVERAGE STACK FLOW RATE=================>       6.20 (DSCF/minute w/HC) :
: AIR TO FUEL RATIO=======================>      11.95 (lb-air/lb-fuel) :
: AVERAGE EXCESS AIR======================>     133.13 (% Stoichiometric) :
: AVERAGE STACK TEMPERATURE===============>     171.58 (Degrees F)      :
: AVERAGE STACK MOISTURE =================>       8.37 (% volume-wet w/HC) :
: AVERAGE CO2=============================>       8.07 (% volume-dry w/HC) :
: AVERAGE O2==============================>      12.23 (% volume-dry w/HC) :
: AVERAGE CO==============================>       0.76 (% volume-dry w/HC) :
:                                                                       :
-------------------------------------------------------------------------

 1  ->  64                                            00:42:46
 0        70.19815                                    08-19-1987
OVERALL EFFICIENCY WITHOUT STOVE TEMPERATURE CHANGE= 68.2 %
```

TABLE 2A
TEST DATA LISTING

CLIENT: WOODCUTTERS RUN NUMBER: 2 DATE OF TEST: 8-14-8

PROJECT NUMBER: SE045-10 MODEL NUMBER: KING
FUEL MOISTURE: 21.75 STACK STATIC PRESSURE(in Hg):
-1.83875E-03
BAROMETRIC PRESSURE (in Hg): 29.84 ROOM TEMPERATURE (F): 74
STOVE WEIGHT (lbs): 407 AMBIENT MOISTURE CONTENT (%): 1.6
CHANGE IN STOVE TEMPERATURE(F): 30 FUEL HHV (BTU/lb): 8765
FUEL COMPOSITION: %C= 51 %H 7.3 %O= 41
METHOD 5 RESULTS: % MOISTURE= 8.49 GRAIN LOADING (gr/scf)= 0

TABLE 2B
FIELD DATA

CLIENT: WOODCUTTERS RUN NUMBER: 2 DATE: 8-14-87

			: Dry and HC free		:			
PT	TIME	WT. FUEL	%CO2	%O2	%CO	WT BLB	DRY BLB	TRACER
1	0	30.10	4.80	14.70	1.33	98.0	135.0	100.0
2	10	28.90	7.90	12.50	1.00	129.0	173.0	100.0
3	20	28.10	7.80	12.60	0.91	131.0	174.0	100.0
4	30	27.00	9.40	11.00	1.44	140.0	185.0	100.0
5	40	25.80	9.70	11.10	0.83	141.0	195.0	100.0
6	50	24.80	9.50	11.40	0.60	139.0	202.0	100.0
7	60	23.80	7.60	13.10	0.77	133.0	189.0	100.0
8	70	23.20	6.00	14.50	1.09	128.0	185.0	100.0
9	80	22.50	5.80	14.50	1.47	127.0	174.0	100.0
10	90	21.40	11.20	9.60	1.41	141.0	198.0	100.0
11	100	20.00	14.50	6.40	1.35	147.0	234.0	100.0
12	110	19.00	10.20	10.80	0.61	139.0	206.0	100.0
13	120	18.40	5.50	15.10	0.30	125.0	178.0	100.0
14	130	18.10	3.80	16.50	0.42	117.0	156.0	100.0
15	140	17.90	3.10	16.80	0.93	111.0	151.0	100.0
16	150	17.60	6.40	13.20	2.26	109.0	155.0	100.0
17	160	16.80	11.30	9.50	1.61	127.0	187.0	100.0
18	170	15.10	16.60	4.00	3.90	140.0	251.0	100.0
19	180	13.00	16.70	3.40	6.38	149.0	232.0	100.0
20	190	12.00	14.60	6.60	0.98	139.0	201.0	100.0
21	200	11.40	11.50	9.40	0.25	132.0	192.0	100.0
22	210	10.90	9.00	11.60	0.33	123.0	178.0	100.0
23	220	10.60	7.70	12.90	0.29	117.0	170.0	100.0
24	230	10.40	6.90	13.60	0.23	113.0	157.0	100.0
25	240	10.20	6.70	13.90	0.22	106.0	148.0	100.0
26	250	10.00	6.90	13.50	0.48	102.0	146.0	100.0
27	260	9.80	9.60	11.20	0.58	101.0	155.0	100.0
28	270	9.20	10.80	9.30	0.61	118.0	175.0	100.0
29	280	8.70	10.50	9.90	0.32	115.0	184.0	100.0
30	290	8.30	10.40	10.40	0.31	111.0	176.0	100.0
31	300	8.10	7.60	13.30	0.09	107.0	149.0	100.0
32	310	7.90	6.40	14.20	0.11	103.0	140.0	100.0
33	320	7.80	5.90	14.60	0.16	100.0	134.0	100.0
34	330	7.70	6.00	14.40	0.44	97.0	134.0	100.0
35	340	7.40	7.90	12.50	1.13	96.0	145.0	100.0
36	350	7.20	8.90	11.70	0.81	97.0	155.0	100.0
37	360	6.80	9.50	11.40	0.39	100.0	165.0	100.0
38	370	6.50	9.50	11.40	0.35	105.0	172.0	100.0
39	380	6.10	9.70	11.30	0.37	106.0	175.0	100.0
40	390	5.80	10.00	11.00	0.28	109.0	174.0	100.0
41	400	5.50	9.50	11.50	0.19	106.0	166.0	100.0
42	410	5.20	8.40	12.60	0.12	104.0	154.0	100.0
43	420	5.10	6.60	14.10	0.09	99.0	144.0	100.0
44	430	4.90	5.80	14.90	0.13	97.0	141.0	100.0
45	440	4.80	6.70	13.80	0.30	96.0	150.0	100.0
46	450	4.60	7.80	13.10	0.25	97.0	159.0	100.0
47	460	4.30	8.30	12.60	0.28	99.0	167.0	100.0
48	470	4.10	8.50	12.40	0.28	100.0	173.0	100.0
49	480	3.80	8.80	12.20	0.29	100.0	176.0	100.0
50	490	3.50	8.50	12.50	0.29	103.0	179.0	100.0

TABLE 2B
FIELD DATA

CLIENT: WOODCUTTERS RUN NUMBER: 2 DATE: 8-14-87

			Dry and HC free					
PT	TIME	WT. FUEL	%CO2	%O2	%CO	WT BLB	DRY BLB	TRACER
51	500	3.20	8.60	12.30	0.32	99.0	180.0	100.0
52	510	3.00	7.70	13.10	0.26	99.0	174.0	100.0
53	520	2.80	7.30	13.60	0.33	98.0	168.0	100.0
54	530	2.60	7.00	13.70	0.37	99.0	166.0	100.0
55	540	2.40	6.40	14.30	0.40	99.0	163.0	100.0
56	550	2.20	6.20	14.40	0.55	100.0	164.0	100.0
57	560	2.00	6.40	14.20	0.75	99.0	165.0	100.0
58	570	1.80	6.10	14.50	0.93	98.0	168.0	100.0
59	580	1.60	5.50	15.00	1.09	99.0	168.0	100.0
60	590	1.40	5.40	15.00	1.28	99.0	168.0	100.0
61	600	1.10	5.20	15.00	1.42	100.0	167.0	100.0
62	610	0.80	5.80	14.30	1.67	100.0	169.0	100.0
63	620	0.30	8.10	12.60	0.44	99.0	181.0	100.0
64	630	0.00	7.90	12.70	0.42	98.0	186.0	100.0

TABLE 3
CHO BALANCED TEST DATA

CLIENT: WOODCUTTERS   RUN NUMBER: 2   DATE: 8-14-87

PT	FLOW RATE (DSCFM w/HC)	DRY BURN RATE (LB/HOUR-CALCULATED)	STACK MOISTURE (%VOLUME-w/HC)	STACK TEMP (F)
1	6.20	1.40	4.94	135.0
2	6.20	2.32	13.96	173.0
3	6.20	2.25	14.86	174.0
4	6.20	2.88	19.24	185.0
5	6.20	2.81	19.50	195.0
6	6.20	2.69	18.12	202.0
7	6.20	2.23	15.35	189.0
8	6.20	1.90	13.09	185.0
9	6.20	1.96	13.02	174.0
10	6.20	3.43	19.40	198.0
11	6.20	4.24	22.02	234.0
12	6.20	2.90	17.99	206.0
13	6.20	1.46	12.01	178.0
14	6.20	0.98	9.66	156.0
15	6.20	0.90	7.84	151.0
16	6.20	2.24	7.08	155.0
17	6.20	3.53	12.57	187.0
18	6.20	5.67	17.13	251.0
19	6.20	6.50	23.43	232.0
20	6.20	4.19	18.15	201.0
21	6.20	3.05	14.75	192.0
22	6.20	2.36	11.18	178.0
23	6.20	2.02	9.16	170.0
24	6.20	1.76	8.26	157.0
25	6.20	1.73	6.48	148.0
26	6.20	1.84	5.49	146.0
27	6.20	2.68	4.92	155.0
28	6.20	2.80	9.35	175.0
29	6.20	2.68	7.97	184.0
30	6.20	2.77	6.94	176.0
31	6.20	1.99	6.72	149.0
32	6.20	1.61	5.97	140.0
33	6.20	1.47	5.44	134.0
34	6.20	1.59	4.75	134.0
35	6.20	2.37	4.12	145.0
36	6.20	2.54	3.98	155.0
37	6.20	2.60	4.31	165.0
38	6.20	2.59	5.33	172.0
39	6.20	2.67	5.50	175.0
40	6.20	2.71	6.40	174.0
41	6.20	2.55	5.82	166.0
42	6.20	2.24	5.72	154.0
43	6.20	1.68	4.84	144.0
44	6.20	1.49	4.49	141.0
45	6.20	1.74	3.94	150.0
46	6.20	2.11	3.83	159.0
47	6.20	2.25	3.99	167.0
48	6.20	2.30	4.01	173.0
49	6.20	2.41	3.90	176.0
50	6.20	2.34	4.55	179.0

TABLE 3
CHO BALANCED TEST DATA

CLIENT: WOODCUTTERS RUN NUMBER: 2 DATE: 8-14-87

PT	FLOW RATE (DSCFM w/HC)	DRY BURN RATE (LB/HOUR-CALCULATED)	STACK MOISTURE (%VOLUME-w/HC)	STACK TEMP (F)
51	6.20	2.35	3.52	180.0
52	6.20	2.06	3.74	174.0
53	6.20	2.02	3.73	168.0
54	6.20	1.90	4.03	166.0
55	6.20	1.76	4.14	163.0
56	6.20	1.75	4.34	164.0
57	6.20	1.89	4.07	165.0
58	6.20	1.89	3.73	168.0
59	6.20	1.78	3.96	168.0
60	6.20	1.80	3.96	168.0
61	6.20	1.75	4.23	167.0
62	6.20	1.98	4.16	169.0
63	6.20	2.21	3.48	181.0
64	6.20	2.12	3.06	186.0

```
OMNI ENVIRONMENTAL SERVICES Inc.                                             PROGRAM NAME IS: REP1.EXE

CURRENT DATE/TIME IS 08-24-1987 / 15:16:17                                 DATA FILE NAME IS: SE045102.DAT

-----------------------------------------------------------------------------------------------------
CLIENT: WOODCUTTERS                                        MODEL NO. KING
-----------------------------------------------------------------------------------------------------
PROJECT NO. SE045-10/2                                     RUN NO. 2
-----------------------------------------------------------------------------------------------------
DATE: AUG  14 1987                                         TECH:  JS/SW/DC
-----------------------------------------------------------------------------------------------------
FUEL MOIST (%) 21.75                                       CAT NO. OMW07
-----------------------------------------------------------------------------------------------------
FUEL CHARGE (LB) 30.1                                      COAL BED (LB)  7.2
-----------------------------------------------------------------------------------------------------
TEST STARTED: AUG  14 1987 12:48:27 PM

                              ***TEST DATA (FORM 1)***

      (2)    WT   (12)   (11)  RM(16)  (19)  (20)  (21)  (22)  (23)  (24)   (25)   (26)   (27)  (32)   (33)
TIME   WT   DIFF   Tin   Tout   TEMP   TOP   BOT  BACK  FBOX  LEFT RIGHT BEFCAT  INCAT AFTCAT  FLUE  DRAFT
-----------------------------------------------------------------------------------------------------------
   0  30.1   0.0    67    68     73    205   203   166   427   235   274      0    477    382   197  -.025
  10  28.9   1.2    66    67     73    196   202   171   371   235   258      0      0    449   260  -.030
  20  28.1   0.8    66    67     73    197   200   169   351   227   246      0    673    483   259  -.030
  30  27.0   1.1    66    67     73    202   199   173   367   230   248      0    931    588   260  -.030
  40  25.8   1.2    66    67     73    230   198   184   388   229   264      0    844    695   312  -.030
  50  24.8   1.0    66    68     73    263   197   194   403   232   273      0      0    735   332  -.035
  60  23.8   1.0    67    68     74    286   198   199   404   233   270      0    793    696   324  -.030
  70  23.2   0.6    67    68     74    283   197   195   399   227   258      0    723    637   310  -.030
  80  22.5   0.7    67    68     74    261   196   185   408   220   248      0      0    581   280  -.030
  90  21.4   1.1    66    67     73    242   194   180   447   217   257    636   1200    713   312  -.035
 100  20.0   1.4    66    68     74    275   194   196   466   230   290    885   1291    951   378  -.040
 110  19.0   1.0    67    68     74    412   192   236   462   250   334    743   1166    971   403  -.035
 120  18.4   0.6    67    69     74    410   194   230   433   247   314    582    882    778   350  -.035
 130  18.1   0.3    68    69     75    343   193   209   407   231   286    474    633    576   283  -.025
 140  17.9   0.2    67    69     75    280   192   186   384   216   259    456    486    463   240  -.025
 150  17.6   0.3    67    68     74    234   189   168   410   207   246    490    470    442   228  -.025
 160  16.8   0.8    66    67     74    211   187   163   458   215   298    736    920    622   270  -.030
 170  15.1   1.7    66    68     74    280   185   189   518   238   366   1077   1349   1004   354  -.040
 180  13.0   2.1    67    68     74    392   186   231   574   282   420   1070   1474   1041   416  -.040
 190  12.0   1.0    68    69     75    432   188   250   551   302   402   1034   1437    966   362  -.035
 200  11.4   0.6    68    70     76    432   192   252   529   296   378    908   1387    919   347  -.035
 210  10.9   0.5    69    70     76    422   193   244   510   283   355    668   1174    871   359  -.035
 220  10.6   0.3    69    70     76    388   192   228   488   268   332    559   1000    744   311  -.025
 230  10.4   0.2    69    70     76    360   192   216   473   261   319    517    917    674   306  -.025
 240  10.2   0.2    68    69     76    322   191   201   456   250   300    476    837    599   270  -.025
 250  10.0   0.2    68    69     75    281   188   184   437   233   283    425    744    538   255  -.020
 260   9.8   0.2    68    69     75    267   186   180   463   231   287    442    775    573   267  -.020
 270   9.2   0.6    67    69     75    260   185   179   520   239   328    512    802    620   299  -.025
 280   8.7   0.5    67    69     75    277   184   192   581   263   375    593    869    677   292  -.025
 290   8.3   0.4    68    69     75    285   186   198   583   273   381    598    876    665   282  -.025
 300   8.1   0.2    68    69     75    292   189   200   531   272   370    557    893    602   277  -.025
 310   7.9   0.2    66    69     75    280   192   194   489   257   337    483    760    544   245  -.025
 320   7.8   0.1    68    69     75    265   192   186   460   244   317    442    686    496   233  -.020
 330   7.7   0.1    66    69     75    245   191   176   438   231   301    407    630    465   224  -.020
 340   7.4   0.3    67    69     75    230   189   167   460   225   305    419    647    481   226  -.020
 350   7.2   0.2    67    66     75    223   187   165   495   226   322    466    688    518   242  -.020
 360   6.8   0.4    67    68     74    229   185   168   522   237   339    509    720    561   247  -.020
 370   6.5   0.3    67    68     74    241   183   176   563   255   351    535    752    592   263  -.020
 380   6.1   0.4    67    68     74    258   184   186   578   267   366    544    813    629   284  -.020
 390   5.8   0.3    67    68     74    276   185   193   571   272   369    569    896    672   285  -.020
 400   5.5   0.3    67    68     74    292   187   198   560   273   370    563    929    672   289  -.025
 410   5.2   0.3    67    69     75    300   190   197   524   267   355    537    944    638   267  -.025
 420   5.1   0.1    67    69     75    292   192   191   485   255   331    485    810    574   246  -.025
 430   4.9   0.2    67    68     75    273   193   183   460   242   312    433    688    520   251  -.020
 440   4.8   0.1    67    68     74    252   192   176   467   234   303    432    682    511   257  -.020
 450   4.6   0.2    67    68     74    243   190   172   502   234   307    466    732    544   275  -.020
 460   4.3   0.3    66    68     74    246   189   174   538   241   318    495    770    584   261  -.020
 470   4.1   0.2    66    67     73    253   189   178   557   252   332    525    755    589   290  -.020
 480   3.8   0.3    66    68     73    257   189   181   581   264   343    543    787    612   295  -.020
```

OMNI ENVIRONMENTAL SERVICES Inc. PROGRAM NAME IS: REP1.EXE
CURRENT DATE/TIME IS 08-24-1987 / 15:18:56 DATA FILE NAME IS: SE045102.DAT

CLIENT: WOODCUTTERS	MODEL NO. KING
PROJECT NO. SE045-10/2	RUN NO. 2
DATE: AUG 14 1987	TECH: JS/SW/DC
FUEL MOIST (%) 21.75	CAT NO. OMW07
FUEL CHARGE (LB) 30.1	COAL BED (LB) 7.2

TEST STARTED: AUG 14 1987 12:48:27 PM

TEST DATA (FORM 1)

TIME	(2) WT	WT DIFF	(12) Tin	(11) Tout	RM(16) TEMP	(19) TOP	(20) BOT	(21) BACK	(22) FBOX	(23) LEFT	(24) RIGHT	(25) BEFCAT	(26) INCAT	(27) AFTCAT	(32) FLUE	(33) DRAFT
490	3.5	0.3	66	68	73	263	190	187	628	274	350	546	786	624	301	-.020
500	3.2	0.3	67	68	73	269	191	190	636	288	345	548	788	628	321	-.020
510	3.0	0.2	66	68	73	270	193	193	621	293	335	528	780	612	317	-.020
520	2.8	0.2	66	68	73	268	195	192	626	290	322	505	755	592	270	-.020
530	2.6	0.2	67	68	74	263	196	190	625	287	313	483	737	576	294	-.020
540	2.4	0.2	66	68	73	257	197	187	573	283	304	471	701	556	284	-.020
550	2.2	0.2	66	67	73	247	198	182	564	278	295	451	681	542	269	-.020
560	2.0	0.2	66	67	73	240	197	178	580	274	288	448	687	550	286	-.020
570	1.8	0.2	66	67	73	238	197	176	566	271	284	445	697	567	285	-.020
580	1.6	0.2	66	67	72	237	198	174	554	266	279	428	656	557	271	-.020
590	1.4	0.2	66	67	72	230	197	171	552	262	274	428	646	547	272	-.020
600	1.1	0.3	65	66	72	223	198	168	563	260	270	420	637	541	267	-.020
610	0.8	0.3	65	66	72	218	198	166	628	259	270	463	660	551	276	-.020
620	0.3	0.5	65	66	72	226	199	175	693	289	293	542	748	604	298	-.025
630	0.0	0.3	65	67	72	243	200	182	667	302	306	538	750	618	313	-.025
AVG:					74	274	192	189	508	253	313	555	827	627	288	-.025

AVERAGE STARTING SURFACE TEMPERATURE (F): 217
AVERAGE ENDING SURFACE TEMPERATURE (F): 247
TEMPERATURE DIFFERENCE (Te-Ts) 30

ALL TEMPERATURES IN F, WEIGHT IN LBS.

AVG. CHANNEL 5: (F) 86.7 AVG. CHANNEL 6: (F) 76.4 AVG. CHANNEL 8: (F) 98.1 AVG. CHANNEL 9: (F) 80.9

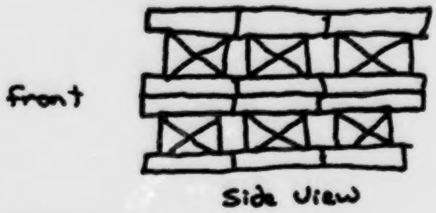
RUN NOTES — TEST

RUN # 2 CLIENT woodcutters PROJECT # 51046-10 MODEL King

BOOTH 1-

COAL BED CHARACTERISTICS
WEIGHT AT START: 7.2 (COOL ✓, GLOWING ___, FLARING ___)

TEST FUEL CONFIGURATION SKETCH (INDICATE VIEW ANGLE)



START UP PROCEDURES:
BY-PASS TIME OPEN 00, CLOSED 1 min.
FUEL LOADING DOOR AJAR 00 FOR 1 MINUTES

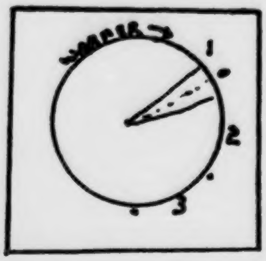
PRIMARY AIR SET High FOR 4 MINUTES

SECONDARY AIR SET fixed FOR N/A MINUTES

TERTIARY AIR SET fixed FOR N/A MINUTES

OTHER fan off for 1st 5 min then set at High.

TEST SETTINGS: (SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY AIR	SECONDARY	TERTIARY	FAN
	fixed	fixed	High

OMNI-SE.005

OMNI™

RUN NOTES — TEST FORM 2

Manufacturer Woodcutter Run No. 2 Model No. King
Date 8/14/87 Project No. SE045-10

Date	Time	Comments
8·14·87	15:05	This test is a low burn, we are trying to duplicate
		run # 41 SE041-1.
		We will be using method 4 moisture only and we
		will be drawing the sample at a constant rate of
		ΔH .6. We will also be using dilution tunnel method
		5G.

OMNI-SE.017

FUEL DATA

OMNI™

CLIENT: Woodcutters
PROJECT: SE045-10
BOOTH: 1

RUN #: 2
DATE: 8.14.8
FUEL LOAD PREPARED BY:

PRE-BURN FUEL
MOISTURE CONTENT (METER -- DRY BASIS)

CALIBRATION: Cal Value(1)=12% Actual Reading 12.50
Cal Value(2)=22% Actual Reading 21.75

Piece	Length	Readings		
1	8 ft	20.00	20.50	20.00
2	ft			
3	ft			

Length of cut pieces: 7 inches

TEST FUEL

FUEL TYPE AND AMOUNT: 2 X 4 0 4 X 4 6
CALCULATED LOAD WEIGHT: 30.1 ACTUAL LOAD WEIGHT: 0 (2 X 4)
FUEL PIECE LENGTH: 17" 30.1 (4 X 4)
30.1 Total

MOISTURE CONTENT (METER -- DRY BASIS)

PIECE	READINGS		
1	19.00	19.00	19.75
2	22.50	22.75	22.50
3	22.25	22.50	22.50
4	21.75	22.00	22.00
5	22.00	22.00	22.25
6	22.50	22.00	22.00
7			
8			
9			
10			

OVERALL TEST FUEL LOAD MOISTURE AVERAGE: 21.74

GRAVIMETRIC ANALYSIS — OVEN-DRIED FUEL SAMPLE

DIMENSIONS: ____ X ____ X ____ = ____ cm^3
DATE/TIME SAMPLE PLACED IN OVEN: __/__/__ ____ AM PM
REMOVED: __/__/__ ____ AM PM
INITIAL WEIGHT (I) ____ - FINAL WEIGHT (F) ____ = NET WEIGHT ____

DRY BASIS MOISTURE % = $\frac{(I - F)}{F}$ X 100 = ____
DRY BASIS BY METER ____

WET BASIS MOISTURE % = $\frac{(I - F)}{F}$ X 100 = ____

TEST FUEL LOAD DENSITY = ____ gm/cm^3

```
OMNI ENVIRONMENTAL SERVICES Inc.                                                    PROGRAM NAME IS: REP1.EXE
CURRENT DATE/TIME IS 08-24-1987 / 15:14:38                                         DATA FILE NAME IS: SE045102.DAT

------------------------------------------------------------------------------------------------------------------
CLIENT: WOODCUTTERS                                                    MODEL NO. KING
------------------------------------------------------------------------------------------------------------------
PROJECT NO. SE045-10/2                                                 RUN NO. 2
------------------------------------------------------------------------------------------------------------------
DATE: AUG  14 1987                                                     TECH:  JS/SW/DC
------------------------------------------------------------------------------------------------------------------
FUEL MOIST (%) 21.75                                                   CAT NO. OMW07
------------------------------------------------------------------------------------------------------------------
PRE BURN STARTED: AUG  14 1987 11:15:41 AM

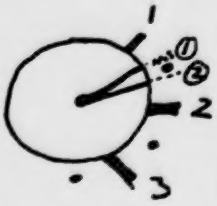
                                        ***PRE BURN DATA***

      (2)    WT    (12)    (11)   RM(16)   (19)    (20)    (21)    (22)    (23)    (24)    (25)    (26)   (27)    (32)    (33)
TIME  WT    DIFF   Tin     Tout   TEMP     TOP     BOT     BACK    FBOX    LEFT   RIGHT  BEFCAT   INCAT  AFTCAT   FLUE    DRAFT
------------------------------------------------------------------------------------------------------------------------------
   0  12.8   0.0    66      67      72     252     207     205     401     297     318       0    1092    893     411    -.040
  10  10.9   1.9    66      68      73     359     208     253     496     336     392       0    1357   1024     410    -.035
  20  10.3   0.6    67      68      73     403     211     262     487     323     375       0    1159    879     393    -.030
  30   9.9   0.4    68      69      74     379     213     242     470     294     337       0     910    715     331    -.030
  40   9.6   0.3    67      69      74     347     213     225     463     275     322       0     955    675     324    -.025
  50   8.9   0.7    67      69      74     339     213     221     489     272     316       0    1142    775     312    -.040
  60   8.7   0.2    67      68      74     333     211     206     453     261     296       0     714    606     265    -.025
  70   8.5   0.2    67      68      74     281     209     194     403     245     275       0     502    489     359    -.025
  80   7.4   1.1    67      68      74     242     208     185     456     240     291       0     499    428     218    -.025
  90   7.3   0.1    67      68      73     212     204     170     428     237     277       0     471    386     201    -.020
```

RUN NOTES — PREBURN

RUN # 7 CLIENT Woodcutters PROJECT # SE045-10 MODEL B.K. King

DESCRIBE OR SKETCH AIR OR THERMOSTAT SETTINGS BELOW:
(SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY:	SECONDARY:	TERTIARY:	FAN:
	Fixed	Fixed	high

PRE-BURN SETTINGS AND ACTIVITIES

TIME	AIR (THERMO) CHANGES			FAN SETTING CHANGE	ADD FUEL +WT.	REMOVE FUEL -WT.	RAKE COAL	COMMENT
	PRIMARY	SECDRY	TERTRY					
@40							X	
@70						X	X	.9 lbs

FINAL

```
                    EPA METHOD 5G RESULTS


                CLIENT WOODCUTTERS
                 MODEL KEJ
             PROJECT # SE045-10
                  RUN# 3
                  DATE 8-21-87
         FILTER HOLDER B


                    EPA METHOD 5G RESULTS



**********************************************************************
PARTICULATE CONCENTRATION (DRY-STANDARD)..  0.0008 (GRAMS/DSCF)
PARTICULATE EMISSION RATE.................   7.234 (GRAMS/HOUR)
ADJUSTED EMISSIONS........................     9.4 (GRAMS/HOUR)
**********************************************************************

TUNNEL TEMPERATURE AVERAGE................      95 (DEGREES FAHRENHEIT)

AVERAGE DELTA P RUN DATA..................   0.041 (INCHES H2O)

(Vm)TOTAL SAMPLE VOLUME (METER CONDITIONS) 267.036 (CUBIC FEET)
AVERAGE GAS METER TEMPERATURE.............      94 (DEGREES FAHRENHEIT)
(vs)AVG. GAS VELOCITY IN DILUTION TUNNEL..   13.76 (FEET/SECOND)
(Qsd)AVG. GAS FLOW RATE IN DILUTION TUNNEL 8900.29 (DSCFH)
(Vmstd)TOTAL SAMPLE VOL. (STD. CONDITIONS) 253.570 (DSCF)
----------------------------------------------------------------------

(mn) TOTAL PARTICULATES...................   206.1 (MG)
AVERAGE DELTA H..........................0.621632 (INCHES H2O)
TOTAL TIME OF TEST........................     490 (MINUTES)
```

```
                              TABLE 1

------------------------------------------------------------------------

RESULTS OF EFFICIENCY TESTING ON THE WOODCUTTERS WOOD STOVE

RUN NUMBER 3   PROJECT NUMBER SE045-10  SERIAL NUMBER C1106

DATE OF TEST: 8-21-87          STOVE MODEL: KEJ                 FINAL

------------------------------------------------------------------------


                    AVERAGE  EFFICIENCIES

************************************************************************
* COMBUSTION= 84.3   % *  HEAT TRANS.= 79.4   % *  OVERALL= 66.9    %
*
************************************************************************


                         EMISSIONS

************************************************************************
* PARTICULATES:       0.000  (grams/Kg-wood)     0.000  (grams/hour)     *
* CARBON MONOXIDE:   72.506  (grams/Kg-wood)    99.972  (grams/hour)     *
************************************************************************


                        TEST  DATA

------------------------------------------------------------------------
!                                                                      :
! BURN RATE=================================>      3.69 (lb/hr-wet)        !
! BURN RATE=================================>      1.38 (kg/hr-dry)        !
! BURN RATE=================================>      1.67 (kg/hr-wet)        !
! FUEL MOISTURE ============================>     17.53 (% Wet basis)      !
! HEAT OUTPUT===============================>  17836.37 (Btu/hr)           !
! FUEL HIGHER HEATING VALUE=================>   8765.00 (Btu/lb-dry)       !
! AVERAGE STACK FLOW RATE===================>      8.24 (DSCF/minute w/HC) !
! AIR TO FUEL RATIO=========================>     12.35 (lb-air/lb-fuel)   !
! AVERAGE EXCESS AIR========================>    132.63 (% Stoichiometric) !
! AVERAGE STACK TEMPERATURE=================>    199.58 (Degrees F)        !
! AVERAGE STACK MOISTURE ===================>     10.14 (% volume-wet w/HC) !
! AVERAGE CO2===============================>      8.08 (% volume-dry w/HC) !
! AVERAGE O2================================>     12.23 (% volume-dry w/HC) !
! AVERAGE CO================================>      0.61 (% volume-dry w/HC) !
!                                                                      !
------------------------------------------------------------------------

 1  ->  50                                              16:03:26
 0       68.64561                                       09-02-1987
OVERALL EFFICIENCY WITHOUT STOVE TEMPERATURE CHANGE= 67.0 %
```

TABLE 2A
TEST DATA LISTING

CLIENT: WOODCUTTERS　RUN NUMBER: 3　DATE OF TEST: 8-21-87

PROJECT NUMBER: SE045-10　MODEL NUMBER: KEJ
FUEL MOISTURE: 21.25　STACK STATIC PRESSURE(in Hg):-.0022065
BAROMETRIC PRESSURE (in Hg): 30.06　ROOM TEMPERATURE (F): 76
STOVE WEIGHT (lbs): 407　AMBIENT MOISTURE CONTENT (%): 1.8
CHANGE IN STOVE TEMPERATURE(F): 10　FUEL HHV (BTU/lb): 8765
FUEL COMPOSITION: %C= 51　%H 7.3　%O= 41
METHOD 5 RESULTS: % MOISTURE= 10.27　GRAIN LOADING (gr/scf)= 0

TABLE 2B
FIELD DATA

CLIENT: WOODCUTTERS RUN NUMBER: 3 DATE: 8-21-87

			Dry and HC free					
PT	TIME	WT. FUEL	%CO2	%O2	%CO	WT BLB	DRY BLB	TRACER
1	0	30.10	7.00	13.20	0.42	109.0	214.0	100.0
2	10	28.00	9.50	10.30	1.31	143.0	239.0	100.0
3	20	26.60	9.60	10.50	0.75	142.0	243.0	100.0
4	30	25.40	8.30	11.90	0.54	139.0	230.0	100.0
5	40	24.40	7.50	13.00	0.43	139.0	219.0	100.0
6	50	23.40	6.70	13.70	0.63	132.0	210.0	100.0
7	60	22.40	10.50	10.40	0.67	140.0	217.0	100.0
8	70	21.40	10.50	10.40	0.67	140.0	217.0	100.0
9	80	19.70	11.60	9.40	0.95	146.0	244.0	100.0
10	90	18.60	9.00	11.70	0.51	138.0	220.0	100.0
11	100	18.00	4.70	15.80	0.24	129.0	188.0	100.0
12	110	17.70	3.20	16.90	0.23	127.0	172.0	100.0
13	120	17.30	5.90	14.40	1.15	126.0	186.0	100.0
14	130	16.50	9.60	10.90	0.66	130.0	195.0	100.0
15	140	14.90	12.60	7.40	3.22	147.0	244.0	100.0
16	150	13.00	13.50	7.20	3.11	147.0	262.0	100.0
17	160	11.50	12.40	8.60	2.28	141.0	208.0	100.0
18	170	10.80	11.00	9.90	0.51	136.0	197.0	100.0
19	180	10.60	6.20	14.20	0.14	120.0	180.0	100.0
20	190	10.40	4.30	16.00	0.13	110.0	162.0	100.0
21	200	10.40	3.50	16.50	0.11	108.0	161.0	100.0
22	210	10.10	7.00	13.60	0.50	109.0	176.0	100.0
23	220	9.70	8.60	12.00	0.47	114.0	195.0	100.0
24	230	9.10	9.10	11.10	0.53	120.0	206.0	100.0
25	240	8.40	9.60	11.10	0.53	123.0	216.0	100.0
26	250	7.70	10.30	10.70	0.48	128.0	219.0	100.0
27	260	7.00	10.30	10.90	0.42	127.0	210.0	100.0
28	270	6.60	9.30	11.90	0.19	127.0	183.0	100.0
29	280	6.20	8.60	12.40	0.05	117.0	175.0	100.0
30	290	6.00	5.50	14.90	0.12	108.0	163.0	100.0
31	300	5.90	4.10	15.90	0.18	101.0	163.0	100.0
32	310	5.60	8.80	12.20	0.43	103.0	178.0	100.0
33	320	5.20	9.10	11.60	0.48	107.0	191.0	100.0
34	330	4.70	9.20	11.30	0.50	105.0	199.0	100.0
35	340	4.30	8.80	11.70	0.51	112.0	207.0	100.0
36	350	3.90	8.30	12.20	0.49	110.0	204.0	100.0
37	360	3.60	8.20	12.30	0.49	108.0	200.0	100.0
38	370	3.30	7.80	12.80	0.49	105.0	195.0	100.0
39	380	3.10	7.80	12.90	0.44	104.0	193.0	100.0
40	390	2.80	7.20	13.20	0.51	103.0	190.0	100.0
41	400	2.50	7.60	13.20	0.54	104.0	190.0	100.0
42	410	2.20	7.30	13.40	0.46	103.0	191.0	100.0
43	420	2.00	7.70	13.20	0.43	105.0	190.0	100.0
44	430	1.70	7.70	13.20	0.53	102.0	190.0	100.0
45	440	1.40	7.70	13.10	0.54	102.0	190.0	100.0
46	450	1.10	7.30	13.50	0.45	103.0	189.0	100.0
47	460	0.90	7.50	13.30	0.48	102.0	189.0	100.0
48	470	0.60	7.80	13.10	0.50	102.0	193.0	100.0
49	480	0.30	7.90	13.00	0.49	104.0	192.0	100.0
50	490	0.00	7.70	13.20	0.51	103.0	194.0	100.0

TABLE 3
CHO BALANCED TEST DATA

CLIENT: WOODCUTTERS RUN NUMBER: 3 DATE: 8-21-87

PT	FLOW RATE (DSCFM w/HC)	DRY BURN RATE (LB/HOUR-CALCULATED)	STACK MOISTURE (%VOLUME-w/HC)	STACK TEMP (F)
1	8.24	2.36	5.06	214.0
2	8.24	3.56	19.80	239.0
3	8.24	3.39	19.04	243.0
4	8.24	2.87	17.65	230.0
5	8.24	2.65	18.02	219.0
6	8.24	2.46	14.50	210.0
7	8.24	3.95	18.68	217.0
8	8.24	3.95	18.68	217.0
9	8.24	4.50	21.59	244.0
10	8.24	3.28	17.41	220.0
11	8.24	1.59	13.79	188.0
12	8.24	0.90	13.42	172.0
13	8.24	2.45	12.48	186.0
14	8.24	3.49	14.03	195.0
15	8.24	5.71	22.27	244.0
16	8.24	6.17	21.70	262.0
17	8.24	5.48	19.57	208.0
18	8.24	4.03	17.06	197.0
19	8.24	2.00	10.17	180.0
20	8.24	1.30	7.31	162.0
21	8.24	0.89	6.73	161.0
22	8.24	2.56	6.48	176.0
23	8.24	3.09	7.41	195.0
24	8.24	3.14	9.23	206.0
25	8.24	3.50	10.10	216.0
26	8.24	3.81	12.23	219.0
27	8.24	3.86	12.08	210.0
28	8.24	3.39	13.03	183.0
29	8.24	3.00	9.21	175.0
30	8.24	1.75	6.66	163.0
31	8.24	1.14	4.73	163.0
32	8.24	3.29	4.68	178.0
33	8.24	3.30	5.32	191.0
34	8.24	3.27	4.44	199.0
35	8.24	3.14	6.28	207.0
36	8.24	2.96	5.75	204.0
37	8.24	2.93	5.28	200.0
38	8.24	2.83	4.59	195.0
39	8.24	2.84	4.39	193.0
40	8.24	2.56	4.23	190.0
41	8.24	2.87	4.50	190.0
42	8.24	2.68	4.19	191.0
43	8.24	2.88	4.78	190.0
44	8.24	2.94	3.97	190.0
45	8.24	2.90	3.97	190.0
46	8.24	2.72	4.27	189.0
47	8.24	2.80	4.00	189.0
48	8.24	2.95	3.85	193.0
49	8.24	2.98	4.43	192.0
50	8.24	2.92	4.08	194.0

OMNI ENVIRONMENTAL SERVICES Inc.

CURRENT DATE/TIME IS 09-02-1987 / 16:41:17

PROGRAM NAME IS: REP1.EXE

DATA FILE NAME IS: SE045103.DAT

CLIENT: WOODCUTTERS

MODEL NO. KEJ-1101

PROJECT NO. SE045-10/3

RUN NO. 3

DATE: AUG 21 1987

TECH: DD

FUEL MOIST (%) 21.25

CAT NO. OMW07

FUEL CHARGE (LB) 30.1

COAL BED (LB) 6.0

TEST STARTED: AUG 21 1987 10:20:29 PM

TEST DATA (FORM 1)

TIME	(2) WT	WT DIFF	(12) Tin	(11) Tout	RM(16) TEMP	(19) TOP	(20) BOT	(21) BACK	(22) FBOX*	(23) LEFT	(24) RIGHT	(25) BEFCAT*	(26) INCAT	(27) AFTCAT	(32) FLUE	(33) DRAFT
0	30.1	0.0	62	63	75	306	275	186	0	337	383	1043	883	661	359	-.035
10	28.0	2.1	63	64	76	322	290	199	0	352	368	1056	1073	771	389	-.040
20	26.6	1.4	64	65	77	348	297	209	0	349	358	1738	1133	818	408	-.040
30	25.4	1.2	64	65	77	367	294	215	0	340	352	1739	1053	761	391	-.040
40	24.4	1.0	54	56	77	370	289	213	0	326	344	659	1067	749	385	-.035
50	23.4	1.0	50	52	77	359	279	204	0	305	327	988	1020	713	366	-.035
60	22.4	1.0	49	51	76	352	274	200	639	297	324	0	1010	707	362	-.035
70	21.4	1.0	48	50	76	361	264	201	0	316	354	784	1240	808	400	-.035
80	19.7	1.7	48	50	75	430	258	219	0	339	389	678	1354	934	451	-.040
90	18.6	1.1	48	50	75	461	255	229	0	345	396	812	1334	927	443	-.040
100	18.0	0.6	48	50	75	468	251	232	0	320	355	1224	1208	808	382	-.035
110	17.7	0.3	48	50	75	413	247	216	0	292	319	0	870	636	338	-.030
120	17.3	0.4	47	49	75	333	241	190	1684	265	293	0	728	576	311	-.030
130	16.5	0.8	55	56	75	298	235	179	0	276	333	904	947	626	328	-.040
140	14.9	1.6	59	60	75	346	232	189	0	307	400	805	1421	908	410	-.035
150	13.0	1.9	61	62	76	438	233	217	0	339	468	828	1507	1003	479	-.040
160	11.5	1.5	58	60	78	497	237	244	0	369	490	1465	1516	982	455	-.035
170	10.8	0.7	52	55	78	497	241	245	0	357	438	929	1556	936	421	-.035
180	10.6	0.2	50	53	78	476	243	238	0	336	395	947	1428	834	393	-.030
190	10.4	0.2	50	52	78	427	241	221	0	311	358	1848	1039	671	347	-.025
200	10.4	0.0	49	51	78	350	237	198	0	284	321	1335	795	545	298	-.025
210	10.1	0.3	49	51	78	311	233	184	0	273	317	1671	799	559	310	-.025
220	9.7	0.4	48	50	77	293	228	177	0	278	337	776	858	596	322	-.025
230	9.1	0.6	47	50	77	300	227	181	0	322	362	1415	957	671	349	-.025
240	8.4	0.7	48	50	77	322	231	197	0	385	372	1358	996	725	371	-.030
250	7.7	0.7	47	50	77	360	238	214	0	408	378	1261	1153	795	393	-.030
260	7.0	0.7	48	50	77	409	245	226	0	411	375	1161	1261	833	388	-.030
270	6.6	0.4	48	50	78	432	251	228	1169	395	360	1169	1420	798	373	-.030
280	6.2	0.4	48	51	73	447	254	225	0	370	340	875	1514	817	370	-.025
290	6.0	0.2	62	63	73	441	249	215	0	339	319	797	1184	726	346	-.025
300	5.9	0.1	65	66	74	382	244	201	0	316	297	700	880	597	299	-.020
310	5.6	0.3	67	68	75	330	241	188	0	315	295	1048	892	604	313	-.020
320	5.2	0.4	68	69	76	310	239	184	0	342	315	1150	878	628	330	-.025
330	4.7	0.5	68	70	77	310	244	188	0	367	337	1108	909	656	339	-.025
340	4.3	0.4	61	64	77	319	251	196	0	390	351	1144	915	674	348	-.025
350	3.9	0.4	62	64	75	326	259	202	1132	398	358	1132	913	670	355	-.025
360	3.6	0.3	67	69	76	329	268	205	0	399	361	1095	912	664	351	-.025
370	3.3	0.3	62	65	77	328	276	205	0	395	359	1059	907	654	336	-.025
380	3.1	0.2	60	62	75	325	280	203	0	386	359	1116	886	640	339	-.025
390	2.8	0.3	67	68	76	318	285	202	0	379	356	1091	891	635	333	-.025
400	2.5	0.3	69	70	77	313	289	200	0	375	353	888	895	632	336	-.025
410	2.2	0.3	60	63	76	310	292	198	0	369	352	881	890	629	334	-.025
420	2.0	0.2	63	64	75	308	294	196	0	360	361	747	876	624	335	-.025
430	1.7	0.3	67	69	76	305	298	193	0	350	389	723	850	616	326	-.025
440	1.4	0.3	66	68	77	302	300	192	0	343	395	682	849	616	332	-.025
450	1.1	0.3	58	61	74	301	300	190	691	343	393	691	807	606	329	-.025
460	0.9	0.2	67	68	76	295	303	187	0	339	394	703	813	599	328	-.025
470	0.6	0.3	69	70	77	292	307	188	0	341	397	705	815	602	331	-.025

```
OMNI ENVIRONMENTAL SERVICES Inc.                                        PROGRAM NAME IS: REP1.EIE

CURRENT DATE/TIME IS 09-02-1987 / 16:43:55                              DATA FILE NAME IS: SE045103.DAT

--------------------------------------------------------------------------------------------------
CLIENT: WOODCUTTERS                                         MODEL NO. KEJ-1101
--------------------------------------------------------------------------------------------------
PROJECT NO. SE045-10/3                                      RUN NO. 3
--------------------------------------------------------------------------------------------------
DATE: AUG  21 1987                                          TECH:  DD
--------------------------------------------------------------------------------------------------
FUEL MOIST (%) 21.25                                        CAT NO. OMW07
--------------------------------------------------------------------------------------------------
FUEL CHARGE (LB) 30.1                                       COAL BED (LB)  6.0
--------------------------------------------------------------------------------------------------
TEST STARTED: AUG  21 1987 10:20:29 PM

                               ***TEST DATA (FORM 1)***

      (2)    WT    (12)   (11)  RM(16)  (19)   (20)   (21)   (22)   (23)   (24)   (25)    (26)   (27)    (32)   (33)
TIME  WT    DIFF   Tin    Tout  TEMP    TOP    BOT    BACK   FBOX*  LEFT   RIGHT  BEFCAT* INCAT  AFTCAT  FLUE   DRAFT
--------------------------------------------------------------------------------------------------------------------
 480  0.3   0.3    59     62    76      294    311    188    698    346    395    698     821    609     331    -.025
 490  0.0   0.3    63     65    75      296    314    188    658    344    393      0     834    616     329    -.025
--------------------------------------------------------------------------------------------------------------------
AVG:                            76      356    263    204    953    343    363    1035    1035   709     360    -.029

--------------------------------------------------------------------------------------------------------------------
AVERAGE STARTING SURFACE TEMPERATURE (F):  297                         ALL TEMPERATURES IN F, WEIGHT IN LBS.
AVERAGE ENDING SURFACE TEMPERATURE   (F):  307
TEMPERATURE DIFFERENCE (Te-Ts) ........... 10

AVG. CHANNEL 5: (F)  93.9    AVG. CHANNEL 6: (F)  90    AVG. CHANNEL 8: (F)  37.3    AVG. CHANNEL 9: (F)  95.2
```

* T.C. malfunction

OMNI™

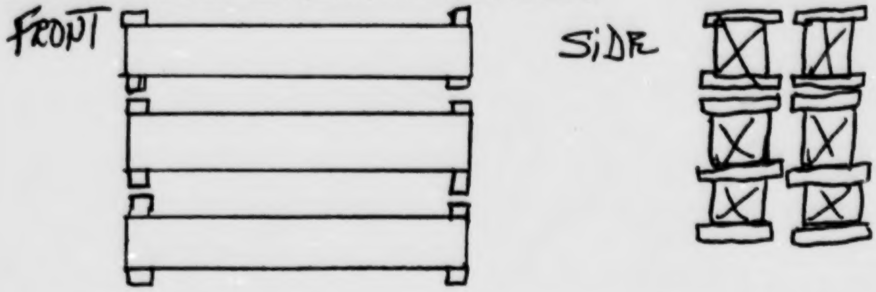
RUN NOTES — TEST

RUN # 3 CLIENT Woodcutters PROJECT # SC045-10 MODEL KEJ

BOOTH 1

COAL BED CHARACTERISTICS
WEIGHT AT START: ______ (COOL ✓, GLOWING ___, FLARING ___)

TEST FUEL CONFIGURATION SKETCH (INDICATE VIEW ANGLE)



START UP PROCEDURES: ·Bypass sealed closed
BY-PASS TIME OPEN 0, CLOSED 0.
FUEL LOADING DOOR AJAR 0 FOR 1.5 MINUTES JUST LONG ENOUGH TO LOAD FUEL

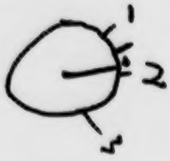
PRIMARY AIR SET Full FOR 4:20 MINUTES
GRADUALLY SET TO TEST SETTING by 4:45 min

SECONDARY AIR SET Fix FOR TEST MINUTES

TERTIARY AIR SET Fix FOR TEST MINUTES

OTHER CAT = 812 @ 5 Min.

TEST SETTINGS: (SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY AIR	SECONDARY	TERTIARY	FAN
	FIXED	FIXED	HIGH

OMNI

RUN NOTES — TEST FORM 2

Manufacturer Woodcutters Run No. 3 Model No. KEJ

Date 8-21-87 Project No. AE045-10

Date	Time	Comments
8/21/87	@ 150+	160 min ΔH Should have been .64.

OMNI

RUN NOTES — TEST FORM 2

Manufacturer WOODCUTTERS Run No. 3 Model No. KING
Date 8/20/87 Project No. SE045-10

Date	Time	Comments
8/20/87	0945	CATALYST # OM-W07 is INSTALLED
		NOTE: CELL IS CHIPPED ON TOP SIDE (BACK)
		WHERE TC PROBE is INSERTED TO
		A DEPTH APPROX 1/3 THE CELL SIZE.
		SMALL CHIP ON TOP TOWARDS FRONT SIDE.
		BOTTOM: 4 CELLS HAVE CHIPPED
		TOWARDS THE BACK OF CATALYST.
		APPROX WHERE TC PROBE IS INSERTED.
		THE OUTSIDE RIM IS CHIPPED IN
		3 CELLS ON BOTTOM ~~SIDE~~, RIGHT SIDE.
		CATALYST GASKET IS WRAPPED ONCE
		AROUND AND OVER LAPED APPROX
		6" ON THE BACK SIDE. THE LEFT
		SIDE HAS AN EXTRA 4" STRIP OF
		GASKET ON THE OUTSIDE TO PRE-
		VENT MOVEMENT SIDE TO SIDE.
		Catalyst was wrapped with a full length
		of gasket and over lapped approx 6" a
		approx 4" piece was added on the outside
		of the left side.

FUEL DATA

OMNI™

CLIENT: WOODCUTTERS - KING
PROJECT: SE045-10
BOOTH: 1

RUN #: 3
DATE: 8/20/87

CATALYST #OM-W07

PRE-BURN FUEL
MOISTURE CONTENT (METER — DRY BASIS)

CALIBRATION: Cal Value(1)=12% Actual Reading 12.50
Cal Value(2)=22% Actual Reading 22.75

Piece	Length	Readings		
1	ft			
2	ft			
3	ft			

Length of cut pieces: _______ inches

TEST FUEL

FUEL TYPE AND AMOUNT: 2 × 4 0 4 × 4 6
CALCULATED LOAD WEIGHT: 30.1
FUEL PIECE LENGTH: 17"

ACTUAL LOAD WEIGHT: _______ (2 × 4)
30.1 (4 × 4)
30.1 Total

MOISTURE CONTENT (METER — DRY BASIS)

PIECE	READINGS		
1	21.75	21.75	21.50
2	20.50	20.25	20.0
3	22.25	22.0	22.25
4	21.50	21.25	21.0
5	20.75	20.75	20.50
6	21.0	21.50	20.75
7			
8			
9			
10			

OVERALL TEST FUEL LOAD MOISTURE AVERAGE: 21.18

GRAVIMETRIC ANALYSIS — OVEN-DRIED FUEL SAMPLE

DIMENSIONS: _____ × _____ × _____ = _____ cm³
DATE/TIME SAMPLE PLACED IN OVEN: __/__/__ _____ AM PM
REMOVED: __/__/__ _____ AM PM
INITIAL WEIGHT (I) _____ - FINAL WEIGHT (F) _____ = NET WEIGHT _____

DRY BASIS MOISTURE % = $\frac{(I - F)}{F}$ × 100 = _______

DRY BASIS BY METER _______

WET BASIS MOISTURE % = $\frac{(I - F)}{F}$ × 100 = _______

TEST FUEL LOAD DENSITY = _______ gm/cm³

FINAL

```
                         EPA METHOD 5G RESULTS


                       CLIENT WOODCUTTERS
                        MODEL KEJ
                    PROJECT # SE045-10
                         RUN# 4
                         DATE 8-24-87
                FILTER HOLDER A


                         EPA METHOD 5G RESULTS



*****************************************************************************
PARTICULATE CONCENTRATION (DRY-STANDARD)..  0.0017 (GRAMS/DSCF)
PARTICULATE EMISSION RATE.................  14.380 (GRAMS/HOUR)
ADJUSTED EMISSIONS........................    16.6 (GRAMS/HOUR)
*****************************************************************************

TUNNEL TEMPERATURE AVERAGE................     114 (DEGREES FAHRENHEIT)

AVERAGE DELTA P RUN DATA..................   0.040 (INCHES H20)

(Vm)TOTAL SAMPLE VOLUME (METER CONDITIONS) 118.451 (CUBIC FEET)
AVERAGE GAS METER TEMPERATURE.............      97 (DEGREES FAHRENHEIT)
(vs)AVG. GAS VELOCITY IN DILUTION TUNNEL..   13.76 (FEET/SECOND)
(Qsd)AVG. GAS FLOW RATE IN DILUTION TUNNEL 8598.89 (DSCFH)
(Vmstd)TOTAL SAMPLE VOL. (STD. CONDITIONS) 111.640 (DSCF)
-----------------------------------------------------------------------------

(mn) TOTAL PARTICULATES...................   186.7 (MG)
AVERAGE DELTA H...........................    0.55 (INCHES H20)
TOTAL TIME OF TEST........................     230 (MINUTES)
```

```
                              TABLE 1

 ----------------------------------------------------------------------

 RESULTS OF EFFICIENCY TESTING ON THE WOODCUTTERS WOOD STOVE

 RUN NUMBER 4   PROJECT NUMBER SE045-10  SERIAL NUMBER C1106

 DATE OF TEST: 8-24-87          STOVE MODEL: KEJ

 ----------------------------------------------------------------------


                     AVERAGE  EFFICIENCIES

 **********************************************************************
 * COMBUSTION= 79.0   % *  HEAT TRANS.= 80.8   % *  OVERALL= 63.9    %
  *
 **********************************************************************


                          EMISSIONS

 **********************************************************************
 * PARTICULATES:       0.000  (grams/Kg-wood)     0.000  (grams/hour)      *
 * CARBON MONOXIDE: 106.404  (grams/Kg-wood)   300.075  (grams/hour)      *
 **********************************************************************


                          TEST  DATA

 ----------------------------------------------------------------------
 !                                                                    :
 ! BURN RATE==================================>       7.46 (lb/hr-wet)          !
 ! BURN RATE==================================>       2.82 (kg/hr-dry)          !
 ! BURN RATE==================================>       3.38 (kg/hr-wet)          !
 ! FUEL MOISTURE =============================>      16.67 (% Wet basis)        !
 ! HEAT OUTPUT================================>   34801.91 (Btu/hr)             !
 ! FUEL HIGHER HEATING VALUE==================>    8765.00 (Btu/lb-dry)         !
 ! AVERAGE STACK FLOW RATE====================>       9.97 (DSCF/minute w/HC)   !
 ! AIR TO FUEL RATIO==========================>       7.09 (lb-air/lb-fuel)     !
 ! AVERAGE EXCESS AIR=========================>      47.23 (% Stoichiometric)   !
 ! AVERAGE STACK TEMPERATURE==================>     293.38 (Degrees F)          !
 ! AVERAGE STACK MOISTURE ====================>      12.13 (% volume-wet w/HC)  !
 ! AVERAGE CO2================================>      12.48 (% volume-dry w/HC)  !
 ! AVERAGE O2=================================>       7.55 (% volume-dry w/HC)  !
 ! AVERAGE CO=================================>       1.52 (% volume-dry w/HC)  !
 !                                                                    !
 ----------------------------------------------------------------------

 1  ->  24                                             16:11:44
 0       66.01031                                      09-02-1987
OVERALL EFFICIENCY WITHOUT STOVE TEMPERATURE CHANGE= 63.7 %
```

FINAL

TABLE 2A
TEST DATA LISTING

CLIENT: WOODCUTTERS RUN NUMBER: 4 DATE OF TEST: 8-24-87

PROJECT NUMBER: SE045-10 MODEL NUMBER: KEJ
FUEL MOISTURE: 20 STACK STATIC PRESSURE(in Hg):
-3.30975E-03
BAROMETRIC PRESSURE (in Hg): 30.03 ROOM TEMPERATURE (F): 77
STOVE WEIGHT (lbs): 407 AMBIENT MOISTURE CONTENT (%): 1.9
CHANGE IN STOVE TEMPERATURE(F): -55 FUEL HHV (BTU/lb): 8765
FUEL COMPOSITION: %C= 51 %H 7.3 %O= 41
METHOD 5 RESULTS: % MOISTURE= 12.46 GRAIN LOADING (gr/scf)= 0

TABLE 2B
FIELD DATA

CLIENT: WOODCUTTERS RUN NUMBER: 4 DATE: 8-24-87

			! Dry and	HC free	!			
PT	TIME	WT. FUEL	%CO2	%O2	%CO	WT BLB	DRY BLB	TRACER
1	0	28.60	14.00	6.90	0.41	138.0	307.0	100.0
2	10	25.30	17.10	2.80	6.92	162.0	334.0	100.0
3	20	22.30	17.80	2.70	5.90	165.0	335.0	100.0
4	30	19.70	17.70	3.20	3.46	156.0	343.0	100.0
5	40	17.10	17.80	3.00	4.16	157.0	346.0	100.0
6	50	14.60	17.00	3.60	3.31	156.0	339.0	100.0
7	60	12.50	16.60	4.40	2.28	149.0	329.0	100.0
8	70	10.60	16.50	4.20	2.02	156.0	326.0	100.0
9	80	8.70	16.70	3.80	1.99	154.0	329.0	100.0
10	90	7.10	15.70	4.90	1.03	153.0	326.0	100.0
11	100	5.90	14.70	6.00	0.54	151.0	321.0	100.0
12	110	4.90	13.20	7.60	0.46	144.0	318.0	100.0
13	120	4.20	10.60	9.90	0.27	142.0	291.0	100.0
14	130	3.80	10.10	10.50	0.29	134.0	290.0	100.0
15	140	3.40	10.00	10.60	0.37	127.0	269.0	100.0
16	150	3.00	10.30	10.40	0.44	128.0	261.0	100.0
17	160	2.60	10.10	10.50	0.36	130.0	258.0	100.0
18	170	2.20	9.50	11.20	0.58	126.0	252.0	100.0
19	180	1.80	9.30	11.40	0.65	126.0	250.0	100.0
20	190	1.50	9.20	11.60	0.72	122.0	245.0	100.0
21	200	1.10	9.30	11.30	0.62	124.0	247.0	100.0
22	210	0.80	9.00	11.40	0.49	132.0	241.0	100.0
23	220	0.40	8.90	11.90	0.60	120.0	238.0	100.0
24	230	0.00	9.30	11.50	0.74	120.0	246.0	100.0

TABLE 3
CHO BALANCED TEST DATA

CLIENT: WOODCUTTERS RUN NUMBER: 4 DATE: 8-24-87

PT	FLOW RATE (DSCFM w/HC)	DRY BURN RATE (LB/HOUR-CALCULATED)	STACK MOISTURE (%VOLUME-w/HC)	STACK TEMP (F)
1	9.97	6.01	9.97	307.0
2	9.97	10.84	21.62	334.0
3	9.97	10.72	23.65	335.0
4	9.97	9.38	17.59	343.0
5	9.97	9.80	18.15	346.0
6	9.97	8.91	17.68	339.0
7	9.97	8.27	14.44	329.0
8	9.97	7.95	17.94	326.0
9	9.97	7.93	16.67	329.0
10	9.97	6.96	16.14	326.0
11	9.97	6.29	15.09	321.0
12	9.97	5.68	12.30	318.0
13	9.97	4.37	12.01	291.0
14	9.97	4.22	8.81	290.0
15	9.97	4.24	6.88	269.0
16	9.97	4.45	7.40	261.0
17	9.97	4.27	8.14	258.0
18	9.97	4.22	6.97	252.0
19	9.97	4.19	7.02	250.0
20	9.97	4.24	5.94	245.0
21	9.97	4.12	6.48	247.0
22	9.97	3.82	9.24	241.0
23	9.97	4.04	5.55	238.0
24	9.97	4.30	5.35	246.0

OMNI ENVIRONMENTAL SERVICES Inc.
CURRENT DATE/TIME IS 09-02-1987 / 16:45:50

PROGRAM NAME IS: REP1.EXE
DATA FILE NAME IS: SE045104.DAT

CLIENT: WOODCUTTERS
MODEL NO. KEJ-1101
PROJECT NO. SE045-10/4
RUN NO. 4
DATE: AUG 25 1987
TECH: DD
FUEL MOIST (%) 20.00
CAT NO. OMW07
FUEL CHARGE (LB) 28.6
COAL BED (LB) 5.7

TEST STARTED: AUG 25 1987 02:03:43 AM

TEST DATA (FORM 1)

TIME	(2) WT	WT DIFF	(12) Tin	(11) Tout	RM(16) TEMP	(19) TOP	(20) BOT	(21) BACK	** (22) FBOX	(23) LEFT	(24) RIGHT	(25) BEFCAT	(26) INCAT	* (27) AFTCAT	(32) FLUE	(33) DRAFT
0	28.6	0.0	59	62	77	456	316	293	1044	535	507	1044	1149	1183	488	-.045
10	25.3	3.3	59	63	78	472	335	295	0	476	477	1252	1334	0	525	-.055
20	22.3	3.0	59	62	78	504	341	298	0	462	467	1402	1538	2150	543	-.055
30	19.7	2.6	59	62	78	542	336	310	0	474	477	1390	1578	1148	568	-.055
40	17.1	2.6	59	62	78	571	326	324	0	492	489	1474	1627	1178	592	-.055
50	14.6	2.5	59	63	78	587	317	333	0	501	504	1490	1571	1188	596	-.055
60	12.5	2.1	59	63	78	610	310	331	0	500	513	1482	1577	1164	583	-.055
70	10.6	1.9	59	63	79	620	305	324	0	499	529	151	1600	1165	589	-.050
80	8.7	1.9	59	63	79	630	303	316	0	502	546	1511	1624	1163	593	-.050
90	7.1	1.6	59	63	79	630	305	317	0	509	559	1465	1613	1168	590	-.050
100	5.9	1.2	59	63	79	615	311	317	0	517	562	1394	1596	1153	582	-.050
110	4.9	1.0	59	63	79	586	320	313	0	519	552	1276	1398	1118	561	-.050
120	4.2	0.7	59	62	78	539	329	300	0	516	532	1081	1138	1062	518	-.050
130	3.8	0.4	58	62	78	486	337	281	0	506	514	1023	1082	0	486	-.045
140	3.4	0.4	57	61	77	441	347	262	0	497	496	945	1038	0	459	-.045
150	3.0	0.4	57	60	76	415	353	250	0	494	487	924	995	1347	448	-.045
160	2.6	0.4	60	62	75	400	359	243	0	488	483	925	1005	2084	438	-.045
170	2.2	0.4	65	68	78	390	362	236	0	476	480	879	984	0	432	-.040
180	1.8	0.4	57	60	76	385	362	233	0	475	473	867	989	0	426	-.040
190	1.5	0.3	63	65	75	381	358	229	0	466	466	843	973	1726	418	-.040
200	1.1	0.4	68	70	77	376	356	224	822	459	463	822	935	1127	416	-.040
210	0.8	0.3	58	62	77	368	354	222	0	468	463	834	919	1497	409	-.040
220	0.4	0.4	56	59	75	363	351	222	820	455	470	820	924	1378	408	-.040
230	0.0	0.4	66	68	76	360	346	219	0	436	471	822	950	1914	410	-.040
AVG:					77	489	335	279	895	488	499	1088	1256	1364	503	-.047

AVERAGE STARTING SURFACE TEMPERATURE (F): 421
AVERAGE ENDING SURFACE TEMPERATURE (F): 366
TEMPERATURE DIFFERENCE (Te-Ts) ....-55

ALL TEMPERATURES IN F, WEIGHT IN LBS.

AVG. CHANNEL 5: (F) 97.3 AVG. CHANNEL 6: (F) 101 AVG. CHANNEL 8: (F) 37.3 AVG. CHANNEL 9: (F) 113.4

* After catalyst thermocouple not functioning properly
** Firebox thermocouple malfunctioning

OMNI

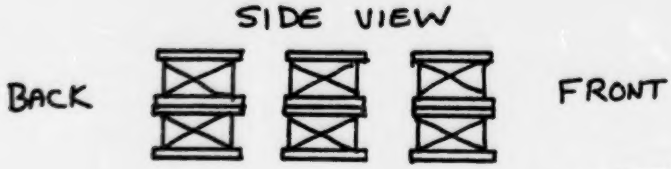
RUN NOTES — TEST

RUN # 4 CLIENT Woodcutters PROJECT # SE045-10 MODEL KEJ

BOOTH 1

COAL BED CHARACTERISTICS
WEIGHT AT START: 5.7 (COOL ___, GLOWING ✓, FLARING ✓)

TEST FUEL CONFIGURATION SKETCH (INDICATE VIEW ANGLE)



START UP PROCEDURES:
BY-PASS TIME OPEN ___, CLOSED ✓.
FUEL LOADING DOOR AJAR To load FOR 2 MINUTES

PRIMARY AIR SET Full High FOR Test MINUTES

SECONDARY AIR SET FixED FOR N.A. MINUTES

TERTIARY AIR SET N.A. FOR N.A. MINUTES

OTHER N.A.

TEST SETTINGS: (SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY AIR	SECONDARY	TERTIARY	FAN
Full High	FixED	N.A.	High

FUEL DATA

OMNI™

CLIENT: Woodcutters
PROJECT: SE045-10
BOOTH: 1

RUN #: 4
DATE: 8-24-87

PRE-BURN FUEL
MOISTURE CONTENT (METER — DRY BASIS)

CALIBRATION: Cal Value(1)=12% Actual Reading ______
Cal Value(2)=22% Actual Reading ______

Piece	Length	Readings		
1	10 ft	22.5	23.0	22.5
2	ft			
3	ft			

Length of cut pieces: 6-7" inches

TEST FUEL

FUEL TYPE AND AMOUNT: 2 × 4 0 4 × 4 6

CALCULATED LOAD WEIGHT: 30.1 ACTUAL LOAD WEIGHT: — (2 × 4)
FUEL PIECE LENGTH: 18.5 28.6 (4 × 4)
28.6 Total

MOISTURE CONTENT (METER — DRY BASIS)

PIECE	READINGS		
1	19.0	21.0	21.0
2	20.0	20.0	19.75
3	19.5	22.0	20.0
4	20.0	19.0	22.0
5	19.5	19.5	19.0
6	19.0	20.0	19.5
7			
8			
9			
10			

OVERALL TEST FUEL LOAD MOISTURE AVERAGE: 20.00

GRAVIMETRIC ANALYSIS — OVEN-DRIED FUEL SAMPLE

DIMENSIONS: ____ × ____ × ____ = ____ cm³
DATE/TIME SAMPLE PLACED IN OVEN: __/__/__ ____ AM PM
REMOVED: __/__/__ ____ AM PM
INITIAL WEIGHT (I) ____ - FINAL WEIGHT (F) ____ = NET WEIGHT ____

DRY BASIS MOISTURE % = $\frac{(I - F)}{F}$ × 100 = ______

DRY BASIS BY METER ______

WET BASIS MOISTURE % = $\frac{(I - F)}{F}$ × 100 = ______

TEST FUEL LOAD DENSITY = ______ gm/cm³

```
OMNI ENVIRONMENTAL SERVICES Inc.                                                   PROGRAM NAME IS: REP1.EIE
CURRENT DATE/TIME IS 09-02-1987 / 16:48:38                                         DATA FILE NAME IS: SE045104.DAT

------------------------------------------------------------------------------------------------------------
CLIENT: WOODCUTTERS                                                   MODEL NO. KEJ-1101
------------------------------------------------------------------------------------------------------------
PROJECT NO. SE045-10/4                                                RUN NO. 4
------------------------------------------------------------------------------------------------------------
DATE: AUG  25 1987                                                    TECH:  DD
------------------------------------------------------------------------------------------------------------
FUEL MOIST (%) 20.00                                                  CAT NO. OMW07
------------------------------------------------------------------------------------------------------------
PRE BURN STARTED: AUG  25 1987 12:24:21 AM

                                         ***PRE BURN DATA***

      (2)    WT   (12)   (11)  RH(16)  (19)   (20)   (21)   (22)   (23)   (24)   (25)    (26)   (27)    (32)   (33)
TIME  WT    DIFF  Tin    Tout  TEMP    TOP    BOT    BACK   FBOX   LEFT   RIGHT  BEFCAT  INCAT  AFTCAT  FLUE   DRAFT
-------------------------------------------------------------------------------------------------------------------
   0  16.6   0.0   52     54    86     584    214    389    1195   532    510      0     1363   1121    600   -.050
  10  15.4   1.2   57     61    79     565    228    336    1222   429    425      0     1563   1051    494   -.040
  20  11.8   3.6   57     61    76     552    234    296    1025   466    414      0     1475   1052    537   -.040
  30  10.0   1.8   57     61    76     552    234    296    1025   466    414      0     1475   1052    537   -.045
  40   8.0   2.0   58     61    76     537    244    309    1366   514    485      0     1595   1088    553   -.045
  50   6.1   1.9   59     62    77     537    261    323    1123   564    518      0     1251   1080    545   -.045
  60   8.1  -2.0   59     63    78     462    290    303     972   518    510      0     1160      0    503   -.050
  70   6.9   1.2   59     62    78     463    304    297    1049   535    499      0     1199   1206    509   -.045
  80   6.0   0.9   58     62    77     456    316    293    1044   535    507      0     1149   1183    488   -.045
```

RUN NOTES — PREBURN

OMNI™

RUN # 4 **CLIENT** Woodcutters **PROJECT #** SE045-10 **MODEL** KEJ

DESCRIBE OR SKETCH AIR OR THERMOSTAT SETTINGS BELOW:
(SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY:	SECONDARY:	TERTIARY:	FAN:
Full High	Fixed	N.A.	High

PRE-BURN SETTINGS AND ACTIVITIES

		AIR (THERMO) CHANGES	FAN SETTING CHANGE	ADD FUEL +WT.	REMOVE FUEL -WT.		
	TIME	PRIMARY SECDRY TERTRY				RAKE COAL	COMMENT
@ 75	+3.3						

FINAL

```
                         EPA METHOD 5G RESULTS

                        CLIENT WOODCUTTERS
                         MODEL KEJ
                     PROJECT # SE045-10
                          RUN# 6
                          DATE 8-25-87
                 FILTER HOLDER B

                         EPA METHOD 5G RESULTS


*************************************************************************
PARTICULATE CONCENTRATION (DRY-STANDARD)..  0.0020 (GRAMS/DSCF)
PARTICULATE EMISSION RATE.................  16.439 (GRAMS/HOUR)
ADJUSTED EMISSIONS........................    18.6 (GRAMS/HOUR)
*************************************************************************

TUNNEL TEMPERATURE AVERAGE................      86 (DEGREES FAHRENHEIT)

AVERAGE DELTA P RUN DATA..................   0.036 (INCHES H20)

(Vm)TOTAL SAMPLE VOLUME (METER CONDITIONS) 374.646 (CUBIC FEET)
AVERAGE GAS METER TEMPERATURE.............      91 (DEGREES FAHRENHEIT)
(vs)AVG. GAS VELOCITY IN DILUTION TUNNEL..   12.73 (FEET/SECOND)
(Qsd)AVG. GAS FLOW RATE IN DILUTION TUNNEL 8369.21 (DSCFH)
(Vmstd)TOTAL SAMPLE VOL. (STD. CONDITIONS) 357.230 (DSCF)
-------------------------------------------------------------------------

(mn) TOTAL PARTICULATES...................   701.7 (MG)
AVERAGE DELTA H...........................    0.55 (INCHES H20)
TOTAL TIME OF TEST........................     730 (MINUTES)
```

```
                              TABLE 1

---------------------------------------------------------------------

RESULTS OF EFFICIENCY TESTING ON THE WOODCUTTERS WOOD STOVE

RUN NUMBER 6   PROJECT NUMBER SE045-10  SERIAL NUMBER C1106

DATE OF TEST: 8-25-87          STOVE MODEL: KEJ

---------------------------------------------------------------------


                  AVERAGE  EFFICIENCIES

*********************************************************************
* COMBUSTION= 75.2  % * HEAT TRANS.= 82.3  % * OVERALL= 61.9   %
 *
*********************************************************************


                          EMISSIONS

*********************************************************************
* PARTICULATES:      0.000  (grams/Kg-wood)     0.000  (grams/hour)       *
* CARBON MONOXIDE: 207.895  (grams/Kg-wood)   189.244  (grams/hour)       *
*********************************************************************


                          TEST  DATA

---------------------------------------------------------------------
!                                                                         :
! BURN RATE=================================>         2.41 (lb/hr-wet)          !
! BURN RATE=================================>         0.91 (kg/hr-dry)          !
! BURN RATE=================================>         1.09 (kg/hr-wet)          !
! FUEL MOISTURE ============================>        16.67 (% Wet basis)        !
! HEAT OUTPUT===============================>     10889.74 (Btu/hr)             !
! FUEL HIGHER HEATING VALUE=================>      8765.00 (Btu/lb-dry)         !
! AVERAGE STACK FLOW RATE===================>         6.18 (DSCF/minute w/HC)   !
! AIR TO FUEL RATIO=========================>        13.92 (lb-air/lb-fuel)     !
! AVERAGE EXCESS AIR========================>       184.63 (% Stoichiometric)   !
! AVERAGE STACK TEMPERATURE=================>       132.03 (Degrees F)          !
! AVERAGE STACK MOISTURE ===================>         8.88 (% volume-wet w/HC)  !
! AVERAGE CO2===============================>         5.86 (% volume-dry w/HC)  !
! AVERAGE O2================================>        14.05 (% volume-dry w/HC)  !
! AVERAGE CO================================>         1.55 (% volume-dry w/HC)  !
!                                                                         :
---------------------------------------------------------------------

 1  ->  74                                              16:25:27
 0         62.32538                                     09-02-1987
OVERALL EFFICIENCY WITHOUT STOVE TEMPERATURE CHANGE= 61.7 %
```

FINAL

TABLE 2A
TEST DATA LISTING

```
CLIENT: WOODCUTTERS                       RUN NUMBER: 6       DATE OF TEST: 8-25-87


PROJECT NUMBER: SE045-10                  MODEL NUMBER: KEJ
FUEL MOISTURE:  20                        STACK STATIC PRESSURE(in Hg):
-1.10325E-03
BAROMETRIC PRESSURE (in Hg):  30.04     ROOM TEMPERATURE (F):  73
STOVE WEIGHT (lbs):  407                  AMBIENT MOISTURE CONTENT (%):  1.6
CHANGE IN STOVE TEMPERATURE(F): -57     FUEL HHV (BTU/lb):  8765
FUEL COMPOSITION:  %C= 51       %H 7.3      %O= 41
METHOD 5 RESULTS: % MOISTURE= 9      GRAIN LOADING (gr/scf)= 0
```

TABLE 2B
FIELD DATA

CLIENT: WOODCUTTERS RUN NUMBER: 6 DATE: 8-25-87

			: Dry and HC free		:			
PT	TIME	WT. FUEL	%CO2	%O2	%CO	WT BLB	DRY BLB	TRACER
1	0	29.30	7.80	13.30	0.11	105.0	154.0	100.0
2	10	28.40	6.30	14.50	0.45	124.0	166.0	100.0
3	20	28.10	3.70	16.60	0.33	117.0	148.0	100.0
4	30	27.90	2.80	17.30	0.55	110.0	130.0	100.0
5	40	27.80	2.20	17.80	0.55	104.0	121.0	100.0
6	50	27.70	2.20	17.80	0.72	103.0	114.0	100.0
7	60	27.60	2.60	17.40	1.24	101.0	112.0	100.0
8	70	27.20	4.60	15.30	2.48	106.0	115.0	100.0
9	80	26.80	7.30	12.80	2.54	111.0	121.0	100.0
10	90	26.20	8.50	11.90	2.15	121.0	131.0	100.0
11	100	25.40	7.90	12.40	2.25	128.0	142.0	100.0
12	110	24.60	6.70	13.20	2.58	128.0	146.0	100.0
13	120	23.90	6.40	13.40	2.78	124.0	141.0	100.0
14	130	23.20	5.70	14.10	2.58	125.0	140.0	100.0
15	140	22.50	5.90	13.80	2.79	125.0	140.0	100.0
16	150	21.90	6.00	13.80	2.92	126.0	141.0	100.0
17	160	21.10	6.10	13.70	3.02	126.0	141.0	100.0
18	170	20.40	5.90	13.90	2.93	125.0	141.0	100.0
19	180	19.70	6.00	13.80	2.96	126.0	140.0	100.0
20	190	19.00	6.10	13.80	2.90	127.0	142.0	100.0
21	200	18.20	7.00	13.20	2.34	128.0	144.0	100.0
22	210	17.40	7.50	12.90	2.02	129.0	149.0	100.0
23	220	16.60	8.10	12.50	1.82	128.0	154.0	100.0
24	230	15.90	8.00	12.70	1.14	129.0	154.0	100.0
25	240	15.40	6.10	14.40	0.68	125.0	142.0	100.0
26	250	15.10	4.20	15.80	0.69	117.0	131.0	100.0
27	260	14.90	3.80	16.00	1.09	112.0	126.0	100.0
28	270	14.60	4.00	15.70	1.66	108.0	121.0	100.0
29	280	14.30	5.80	14.30	1.88	109.0	122.0	100.0
30	290	13.80	6.70	13.50	2.26	112.0	128.0	100.0
31	300	13.30	7.40	12.90	2.20	116.0	130.0	100.0
32	310	12.70	7.70	12.70	2.37	117.0	136.0	100.0
33	320	12.00	8.30	12.20	2.41	121.0	139.0	100.0
34	330	11.40	8.10	12.20	1.45	116.0	138.0	100.0
35	340	10.90	7.20	13.00	0.95	112.0	135.0	100.0
36	350	10.70	6.00	14.30	0.67	109.0	128.0	100.0
37	360	10.40	4.70	15.40	0.66	105.0	123.0	100.0
38	370	10.30	3.90	16.10	0.80	102.0	116.0	100.0
39	380	10.10	3.60	18.50	1.13	98.0	113.0	100.0
40	390	10.00	4.10	15.50	1.85	95.0	114.0	100.0
41	400	9.70	4.40	15.20	2.05	93.0	115.0	100.0
42	410	9.60	4.70	15.00	2.09	95.0	115.0	100.0
43	420	9.40	4.70	15.10	1.85	94.0	117.0	100.0
44	430	9.10	4.90	14.90	1.93	95.0	118.0	100.0
45	440	8.90	5.40	14.50	2.04	99.0	124.0	100.0
46	450	8.60	5.10	14.70	2.20	101.0	126.0	100.0
47	460	8.20	5.10	14.70	2.29	101.0	130.0	100.0
48	470	7.90	5.30	14.50	2.18	103.0	132.0	100.0
49	480	7.50	5.50	14.40	2.12	105.0	135.0	100.0
50	490	7.10	6.40	13.80	1.78	107.0	137.0	100.0

TABLE 2B
FIELD DATA

CLIENT: WOODCUTTERS RUN NUMBER: 6 DATE: 8-25-87

			Dry and HC free					
PT	TIME	WT. FUEL	%CO2	%O2	%CO	WT BLB	DRY BLB	TRACER
51	500	6.80	6.10	14.00	1.78	107.0	135.0	100.0
52	510	6.50	6.10	14.10	1.68	106.0	137.0	100.0
53	520	6.10	6.30	13.90	1.66	106.0	137.0	100.0
54	530	5.60	6.70	13.70	1.67	109.0	138.0	100.0
55	540	5.20	6.70	13.80	1.53	109.0	142.0	100.0
56	550	4.80	6.90	13.60	1.48	111.0	143.0	100.0
57	560	4.20	9.00	12.00	1.02	115.0	149.0	100.0
58	570	3.70	8.20	12.80	0.72	112.0	146.0	100.0
59	580	3.40	6.70	14.00	0.42	110.0	135.0	100.0
60	590	3.20	5.40	15.10	0.41	102.0	126.0	100.0
61	600	3.10	5.10	15.30	0.61	97.0	121.0	100.0
62	610	2.90	6.00	14.30	1.46	97.0	121.0	100.0
63	620	2.60	7.80	12.80	1.34	103.0	129.0	100.0
64	630	2.20	8.20	12.30	1.31	108.0	133.0	100.0
65	640	1.80	8.50	12.10	1.13	113.0	140.0	100.0
66	650	1.30	8.50	12.10	0.84	111.0	142.0	100.0
67	660	1.00	6.80	13.70	0.57	106.0	134.0	100.0
68	670	0.90	5.50	15.00	0.34	100.0	125.0	100.0
69	680	0.70	4.00	16.30	0.38	94.0	118.0	100.0
70	690	0.70	3.30	16.80	0.53	89.0	114.0	100.0
71	700	0.60	4.60	15.20	1.82	88.0	116.0	100.0
72	710	0.30	6.50	13.80	1.65	92.0	120.0	100.0
73	720	0.10	6.90	13.30	1.62	94.0	124.0	100.0
74	730	0.00	6.90	13.30	1.38	93.0	127.0	100.0

TABLE 3
CHO BALANCED TEST DATA

CLIENT: WOODCUTTERS   RUN NUMBER: 6   DATE: 8-25-87

PT	FLOW RATE (DSCFM w/HC)	DRY BURN RATE (LB/HOUR-CALCULATED)	STACK MOISTURE (%VOLUME-w/HC)	STACK TEMP (F)
1	6.18	2.11	6.20	154.0
2	6.18	1.78	12.44	166.0
3	6.18	0.91	10.30	148.0
4	6.18	0.72	8.59	130.0
5	6.18	0.53	7.17	121.0
6	6.18	0.61	7.17	114.0
7	6.18	0.94	6.73	112.0
8	6.18	1.96	7.96	115.0
9	6.18	2.72	9.24	121.0
10	6.18	2.94	12.46	131.0
11	6.18	2.81	15.09	142.0
12	6.18	2.53	14.95	146.0
13	6.18	2.52	13.34	141.0
14	6.18	2.26	13.81	140.0
15	6.18	2.37	13.81	140.0
16	6.18	2.47	14.22	141.0
17	6.18	2.54	14.22	141.0
18	6.18	2.45	13.77	141.0
19	6.18	2.49	14.25	140.0
20	6.18	2.52	14.63	142.0
21	6.18	2.59	15.02	144.0
22	6.18	2.64	15.31	149.0
23	6.18	2.76	14.66	154.0
24	6.18	2.48	15.14	154.0
25	6.18	1.74	13.74	142.0
26	6.18	1.11	10.93	131.0
27	6.18	1.12	9.38	126.0
28	6.18	1.40	8.31	121.0
29	6.18	2.07	8.58	122.0
30	6.18	2.48	9.30	128.0
31	6.18	2.66	10.60	130.0
32	6.18	2.84	10.74	136.0
33	6.18	3.03	12.17	139.0
34	6.18	2.52	10.31	138.0
35	6.18	2.05	9.04	135.0
36	6.18	1.65	8.35	128.0
37	6.18	1.26	7.37	123.0
38	6.18	1.08	6.83	116.0
39	6.18	1.78	5.96	113.0
40	6.18	1.47	5.23	114.0
41	6.18	1.64	4.77	115.0
42	6.18	1.76	5.20	115.0
43	6.18	1.69	4.90	117.0
44	6.18	1.77	5.08	118.0
45	6.18	1.98	5.77	124.0
46	6.18	1.94	6.19	126.0
47	6.18	1.98	6.04	130.0
48	6.18	1.98	6.48	132.0
49	6.18	2.04	6.92	135.0
50	6.18	2.21	7.41	137.0

TABLE 3
CHO BALANCED TEST DATA

CLIENT: WOODCUTTERS   RUN NUMBER: 6   DATE: 8-25-87

PT	FLOW RATE (DSCFM w/HC)	DRY BURN RATE (LB/HOUR-CALCULATED)	STACK MOISTURE (%VOLUME-w/HC)	STACK TEMP (F)
51	6.18	2.10	7.49	135.0
52	6.18	2.09	7.12	137.0
53	6.18	2.13	7.12	137.0
54	6.18	2.29	7.98	138.0
55	6.18	2.26	7.83	142.0
56	6.18	2.29	8.42	143.0
57	6.18	2.76	9.54	149.0
58	6.18	2.44	8.63	146.0
59	6.18	1.84	8.40	135.0
60	6.18	1.45	6.45	126.0
61	6.18	1.43	5.42	121.0
62	6.18	2.00	5.42	121.0
63	6.18	2.49	6.60	129.0
64	6.18	2.54	7.86	133.0
65	6.18	2.57	9.19	140.0
66	6.18	2.45	8.45	142.0
67	6.18	1.87	7.24	134.0
68	6.18	1.44	5.98	125.0
69	6.18	1.01	4.86	118.0
70	6.18	0.84	4.01	114.0
71	6.18	1.65	3.74	116.0
72	6.18	2.20	4.37	120.0
73	6.18	2.26	4.63	124.0
74	6.18	2.16	4.30	127.0

OMNI ENVIRONMENTAL SERVICES Inc.
PROGRAM NAME IS: REP1.EXE

CURRENT DATE/TIME IS 06-26-1987 / 13:21:13
DATA FILE NAME IS: SE045106.DAT

CLIENT: WOODCUTTERS
MODEL NO. KEJ

PROJECT NO. SE045-10/#6
RUN NO. #6

DATE: AUG 30 1987
TECH: JS/SD

FUEL MOIST (%) 20
CAT NO. OMW07

FUEL CHARGE (LB) 29.3
COAL BED (LB) 6

TEST STARTED: AUG 30 1987 01:50:51 AM

TEST DATA (FORM 1)

TIME	(2) WT	WT DIFF	(12) Tin	(11) Tout	RM(16) TEMP	(19) TOP	(20) BOT	(21) BACK	(22) FBOX *	(23) LEFT	(24) RIGHT	(25) BEFCAT	(26) INCAT	(27) AFTCAT *	(32) FLUE	(33) DRAFT
0	29.3	0.0	57	59	71	294	189	186	0	334	352	677	932	0	304	-.020
10	28.4	0.9	64	65	72	306	191	192	0	302	303	526	955	0	303	-.025
20	28.1	0.3	66	67	73	284	192	184	0	260	258	420	609	0	263	-.025
30	27.9	0.2	66	67	74	246	192	168	0	228	228	353	422	0	224	-.020
40	27.8	0.1	67	68	74	211	187	154	0	208	205	311	349	0	198	-.015
50	27.7	0.1	66	67	74	185	186	141	0	191	188	283	311	0	180	-.015
60	27.6	0.1	66	67	74	163	184	130	0	177	173	276	294	0	164	-.015
70	27.2	0.4	66	67	73	151	182	122	0	171	164	287	311	0	163	-.015
80	26.8	0.4	66	67	74	146	181	118	0	179	167	312	354	0	170	-.010
90	26.2	0.6	66	67	73	149	182	119	355	195	178	355	407	0	185	-.010
100	25.4	0.8	66	67	73	157	183	125	0	216	194	484	484	0	205	-.020
110	24.6	0.8	66	67	73	170	185	131	0	225	203	410	466	0	213	-.020
120	23.9	0.7	66	67	73	177	186	134	0	226	209	464	464	0	214	-.020
130	23.2	0.7	66	67	73	181	188	136	423	225	212	423	463	0	216	-.020
140	22.5	0.7	66	67	73	183	189	136	0	224	217	430	469	0	214	-.020
150	21.9	0.6	66	67	73	185	191	135	0	222	221	444	479	0	215	-.020
160	21.1	0.8	66	67	73	187	194	135	0	223	225	448	487	0	220	-.020
170	20.4	0.7	66	67	73	189	196	135	0	223	230	448	494	0	218	-.020
180	19.7	0.7	66	67	73	192	198	133	0	226	234	443	501	0	221	-.020
190	19.0	0.7	66	67	73	193	201	134	0	227	240	445	514	0	223	-.020
200	18.2	0.8	66	67	73	196	204	134	0	231	249	471	659	0	233	-.020
210	17.4	0.8	66	67	73	218	207	138	0	234	258	492	997	0	259	-.020
220	16.6	0.8	66	67	73	248	209	144	0	234	265	512	1082	0	276	-.020
230	15.9	0.7	66	67	73	280	211	150	530	237	271	530	1096	0	286	-.020
240	15.4	0.5	66	67	73	298	213	153	0	235	271	496	957	0	269	-.020
250	15.1	0.3	66	67	73	279	215	150	0	226	260	426	736	0	242	-.020
260	14.9	0.2	66	67	73	254	214	145	0	218	251	391	630	0	227	-.020
270	14.6	0.3	66	67	73	225	211	138	0	210	243	369	505	0	210	-.015
280	14.3	0.3	65	67	73	203	207	132	0	205	247	390	438	0	207	-.015
290	13.8	0.5	65	67	72	188	202	128	419	211	267	419	420	0	211	-.010
300	13.3	0.5	65	66	72	183	197	127	0	218	286	454	456	0	217	-.010
310	12.7	0.6	65	66	72	186	192	129	0	228	307	476	498	0	229	-.010
320	12.0	0.7	65	66	72	192	189	132	0	236	327	536	536	0	238	-.015
330	11.4	0.6	65	66	72	214	187	138	551	245	342	551	828	0	258	-.015
340	10.9	0.5	65	67	72	238	185	143	0	243	336	536	900	0	261	-.015
350	10.7	0.2	66	67	72	252	185	145	0	239	324	502	666	0	251	-.015
360	10.4	0.3	66	67	72	251	184	144	0	231	306	457	776	0	237	-.015
370	10.3	0.1	66	67	72	238	183	141	0	223	288	418	670	0	222	-.015
380	10.1	0.2	65	66	72	218	181	136	0	214	273	393	540	0	209	-.015
390	10.0	0.1	65	66	72	199	178	130	0	206	264	395	449	0	205	-.015
400	9.7	0.3	65	66	71	185	175	126	0	203	264	406	420	0	200	-.010
410	9.6	0.1	65	66	71	178	172	123	0	202	265	409	424	0	200	-.015
420	9.4	0.2	64	65	71	175	170	122	0	203	269	414	455	0	202	-.015
430	9.1	0.3	64	65	71	175	169	123	0	204	275	418	477	0	203	-.015
440	8.9	0.2	65	66	72	179	168	126	0	210	288	433	488	0	212	-.015
450	8.6	0.3	66	68	74	184	170	130	0	215	292	435	522	0	220	-.015
460	8.2	0.4	67	68	75	190	174	133	0	217	293	436	602	0	227	-.015
470	7.9	0.3	68	69	76	197	180	136	0	217	294	438	680	0	234	-.015
480	7.5	0.4	68	69	76	205	185	139	0	219	295	457	757	0	241	-.015

OMNI ENVIRONMENTAL SERVICES Inc. PROGRAM NAME IS: REP1.EXE

CURRENT DATE/TIME IS 08-26-1987 / 13:23:53 DATA FILE NAME IS: SE045106.DA

CLIENT: WOODCUTTERS	MODEL NO. KEJ
PROJECT NO. SE045-10/#6	RUN NO. #6
DATE: AUG 30 1987	TECH: JS/SD
FUEL MOIST (%) 20	CAT NO. OMW07
FUEL CHARGE (LB) 29.3	COAL BED (LB) 6

TEST STARTED: AUG 30 1987 01:50:51 AM

TEST DATA (FORM 1)

TIME	(2) WT	WT DIFF	(12) Tin	(11) Tout	RM(16) TEMP	(19) TOP	(20) BOT	(21) BACK	(22) FBOX*	(23) LEFT	(24) RIGHT	(25) BEFCAT	(26) INCAT	(27) AFTCAT*	(32) FLUE	(33) DRAFT
490	7.1	0.4	62	65	77	215	192	143	0	228	302	473	810	0	248	-.015
500	6.8	0.3	62	64	74	226	198	143	0	227	298	466	881	0	250	-.020
510	6.5	0.3	66	67	74	234	204	144	0	229	295	463	907	0	252	-.020
520	6.1	0.4	66	67	74	240	209	144	0	228	293	463	925	0	255	-.020
530	5.6	0.5	66	67	74	247	213	145	0	231	289	471	978	0	259	-.020
540	5.2	0.4	66	67	74	255	216	146	0	234	283	464	1001	0	264	-.025
550	4.8	0.4	66	67	73	263	218	148	0	236	277	467	1050	0	267	-.020
560	4.2	0.6	66	67	73	273	220	150	0	246	274	501	1094	0	275	-.020
570	3.7	0.5	66	67	73	288	222	155	0	264	272	527	1164	0	283	-.020
580	3.4	0.3	66	67	73	300	223	158	0	267	267	495	1046	0	271	-.020
590	3.2	0.2	66	67	73	290	224	155	0	267	256	438	862	0	252	-.020
600	3.1	0.1	66	67	73	266	224	149	0	265	245	405	757	0	231	-.015
610	2.9	0.2	65	67	73	242	221	143	0	262	236	399	742	0	225	-.015
620	2.6	0.3	65	66	72	228	218	139	0	277	236	433	767	0	229	-.015
630	2.2	0.4	65	67	72	222	215	140	0	301	245	477	850	0	238	-.015
640	1.8	0.4	66	67	72	229	213	145	0	318	253	510	953	0	258	-.020
650	1.3	0.5	66	67	72	250	211	152	0	330	262	525	998	0	271	-.020
660	1.0	0.3	66	67	72	272	211	158	0	319	259	514	1017	0	260	-.020
670	0.9	0.1	66	67	73	278	212	158	0	303	251	467	915	0	249	-.015
680	0.7	0.2	66	67	72	263	212	153	0	282	237	404	741	0	229	-.015
690	0.7	0.0	66	67	72	243	210	146	0	266	226	369	639	0	216	-.015
700	0.6	0.1	66	67	72	219	206	139	0	254	215	361	659	0	207	-.015
710	0.3	0.3	65	66	72	204	203	134	0	266	215	394	682	0	208	-.015
720	0.1	0.2	65	66	72	197	201	133	0	288	222	428	674	0	215	-.015
730	0.0	0.1	65	66	72	197	203	135	0	303	230	452	729	0	222	-.015
AVG:					73	220	197	141	455	238	257	441	682	0	231	-.017

AVERAGE STARTING SURFACE TEMPERATURE (F): 271
AVERAGE ENDING SURFACE TEMPERATURE (F): 214
TEMPERATURE DIFFERENCE (Te-Ts) ....-57

ALL TEMPERATURES IN F, WEIGHT IN LBS.

AVG. CHANNEL 5: (F) 90.9 AVG. CHANNEL 6: (F) 83.6 AVG. CHANNEL 8: (F) 77.5 AVG. CHANNEL 9: (F) 85.7

* T.C. malfunction

OMNI™ PAGE 1 OF 1

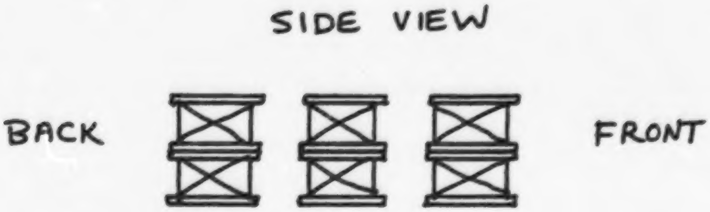
RUN NOTES — TEST

RUN # 6 CLIENT Woodcutters PROJECT # se045·10 MODEL King

BOOTH 1

COAL BED CHARACTERISTICS
WEIGHT AT START: 6.0 (COOL ___, GLOWING ✓, FLARING ___)

TEST FUEL CONFIGURATION SKETCH (INDICATE VIEW ANGLE)



START UP PROCEDURES:
BY-PASS TIME OPEN ______, CLOSED ✓.
FUEL LOADING DOOR AJAR To load FOR 2 MINUTES

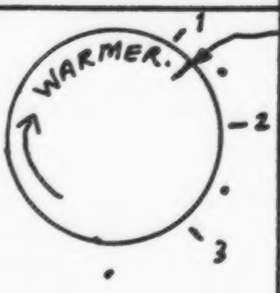
PRIMARY AIR SET Full High FOR 4.75 MINUTES
Then shut down slowly to Test setting

SECONDARY AIR SET Fixed FOR N.A. MINUTES

TERTIARY AIR SET N.A. FOR N.A. MINUTES

OTHER N.A.

TEST SETTINGS: (SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY AIR	SECONDARY	TERTIARY	FAN
	Between 1 & 1.5 S.D. Fixed	N. A.	High

OMNI-SE.005

PAGE 1 OF 1

RUN NOTES — TEST FORM 2

Manufacturer Woodcutters Run No. 6 Model No. King

Date 8·25·87 Project No. SE045·10

Date	Time	Comments
8-25-		The catalyst temp at the
		first 5 minutes was at
		1050°F. S.D.

OMNI

FUEL DATA

CLIENT: Woodcutters
PROJECT: 35045-10
BOOTH: 1
RUN #: 6
DATE: 8.25.87
FUEL LOAD PREPARED BY: H

PRE-BURN FUEL
MOISTURE CONTENT (METER — DRY BASIS)

CALIBRATION: Cal Value(1)=12% Actual Reading 12.00
Cal Value(2)=22% Actual Reading 22.75

Piece	Length	Readings		
1	8 ft	20.00	19.75	19.75
2	ft			
3	ft			

Length of cut pieces: 6" inches

TEST FUEL

FUEL TYPE AND AMOUNT: 2 X 4 0 4 X 4 6
CALCULATED LOAD WEIGHT: 30.6
ACTUAL LOAD WEIGHT: 0 (2 X 4)
6 (4 X 4)
29.3 Total
FUEL PIECE LENGTH: 17"

MOISTURE CONTENT (METER — DRY BASIS)

PIECE	READINGS		
1	22.50	22.50	22.75
2	19.50	19.50	19.75
3	19.25	19.50	19.50
4	19.50	19.25	19.25
5	20.00	20.00	20.75
6	19.00	19.00	19.50
7			
8			
9			
10			

OVERALL TEST FUEL LOAD MOISTURE AVERAGE: 20.00

GRAVIMETRIC ANALYSIS — OVEN-DRIED FUEL SAMPLE

DIMENSIONS: ______ X ______ X ______ = ______ cm³
DATE/TIME SAMPLE PLACED IN OVEN: __/__/__ ______ AM PM
REMOVED: __/__/__ ______ AM PM
INITIAL WEIGHT (I) ____ - FINAL WEIGHT (F) ____ = NET WEIGHT ____

DRY BASIS MOISTURE % = $\frac{(I - F)}{F}$ X 100 = ______

DRY BASIS BY METER ______

WET BASIS MOISTURE % = $\frac{(I - F)}{I}$ X 100 = ______

TEST FUEL LOAD DENSITY = ______ gm/cm³

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OMNI ENVIRONMENTAL SERVICES Inc.                                          PROGRAM NAME IS: KEP1.EIE

CURRENT DATE/TIME IS 08-26-1987 / 13:19:30                               DATA FILE NAME IS: SE045106.DAT


---------------------------------------------------------------------------------------------------
CLIENT: WOODCUTTERS                                        MODEL NO. KEJ
---------------------------------------------------------------------------------------------------
PROJECT NO. SE045-10/#6                                    RUN NO. #6
---------------------------------------------------------------------------------------------------
DATE: AUG  30 1987                                         TECH:  JS/SD
---------------------------------------------------------------------------------------------------
FUEL MOIST (%) 20                                          CAT NO. OMW07
---------------------------------------------------------------------------------------------------
PRE BURN STARTED: AUG  30 1987 12:29:20 AM

                                  ***PRE BURN DATA***

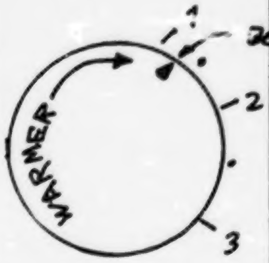
      (2)    WT   (12)   (11)  RM(16)  (19)  (20)  (21)  (22)  (23)   (24)   (25)   (26)   (27)   (32)   (33)
TIME   WT   DIFF   Tin   Tout   TEMP   TOP   BOT   BACK  FBOX  LEFT  RIGHT  BEFCAT INCAT AFTCAT  FLUE  DRAFT
---------------------------------------------------------------------------------------------------------------
 40   9.4   -9.4   56     57     81    303   208   195   591   293    318      0   1046     0    297   -.025
 50   8.7    0.7   53     55     81    307   208   196   693   298    319      0   1221     0    311   -.025
 60   8.2    0.5   50     52     80    368   207   196   887   279    299      0   1626     0    330   -.025
 70   7.7    0.5   49     51     79    411   205   201   749   272    295      0   1434     0    337   -.025
 80   7.5    0.2   48     50     79    410   204   197   586   264    279      0   1107     0    312   -.025
 90   7.3    0.2   48     50     79    363   201   189   477   255    265      0    836     0    280   -.020
100   7.1    0.2   46     50     77    283   196   171   473   242    250      0    596     0    266   -.020
110   6.9    0.2   47     49     77    265   195   168   561   271    279      0    712     0    281   -.020
120   6.4    0.5   47     49     73    269   193   176     0   318    334    689    870     0    319   -.035
```

OMNI™

RUN NOTES — PREBURN

RUN # 6 CLIENT Woodcutters PROJECT # SE045-10 MODEL King

DESCRIBE OR SKETCH AIR OR THERMOSTAT SETTINGS BELOW:
(SETTINGS MUST BE ACCURATE AND REPRODUCIBLE)

PRIMARY:	SECONDARY:	TERTIARY:	FAN:
 Between #1 + 1.5	fixed	N/A	ON High

PRE-BURN SETTINGS AND ACTIVITIES

TIME	AIR (THERMO) CHANGES PRIMARY SECDRY TERTRY	FAN SETTING CHANGE	ADD FUEL +WT.	REMOVE FUEL -WT.	RAKE COAL	COMMENT
@30	Primary air Setting from 2 to 3.5				*	
@50	Primary air setting from 3.5 to 4.25				*	

Blaze King® Canada Ltd.

1290 COMMERCIAL WAY, PENTICTON, B.C. V2A 3H5
(604) 493-7101

September 23, 1987

WOODCUTTERS MFG., INC.
3301 E. Isaacs
WALLA WALLA, Washington
99362

Attention: Mr. Larry Canaday

Re: Stove Assembly Procedures in effect September 9, 1987

Dear Larry:

In reply to previous communication regarding procedures used by Blaze King Canada Ltd.:

1) Thermostats are set as per drawings, as per U.S. models which meet Omni testing for Oregon emission.
2) By pass door rope is cemented in position using furnace cement supplied by Woodcutters Mfg., Walla Walla, Washington.
3) Combustors will be shipped in original box inside the stove to be installed on site, all points north.
4) Quality control is in effect to monitor welding of by pass door corners.

We trust the above information will prove adequate.

Yours truly,
BLAZE KING CANADA LTD.

Richard Till
Production Supervisor

ag

RECEIVED OCT 0 1 1987

APPENDIX F

PROJECT PARTICIPANT PROFILES

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W01

HOME TYPE:	Newer Single Family Custom Split Level	FLOOR AREA:	183 square meters (1965 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 7

WOODSTOVE LOCATION: Unfinished Basement

CHIMNEY SYSTEM DESCRIPTION:

18 cm (7 inches) single wall from flue collar to ceiling thimble (1.7 meters [5.6 feet])

18 cm by 23 cm (7 inches by 9 inches) packed pipe from ceiling to exit (4.0 meters [13.1 feet] within walls of house, 0.8 meters [2.6 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: RSF "65"

AGE: 4 years

FIREBOX VOLUME: 0.1348 cubic meters (4.76 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Double Wall Flue Pipe*

TECHNOLOGY TYPE: N/A

FIREBOX VOLUME: N/A

PARTICIPANT COMMENTS

Participant felt that the Security system produced better draft for the stove; however, heavy creosote accumulation caused a hazard and contributed to smoke spillage problems. The James A. Ryder Chimney System did not have any noticeable effect on the stove performance. Participant felt that the stove performed in a similar manner as with the original single wall system in place.

GENERAL COMMENTS

* Used two different styles of double wall pipe during the study. Replaced the single wall with Security 18 cm (7 inch) vented double wall pipe on January 14, 1987.

Replaced Security pipe with James A. Ryder 18 cm (7 inch) air-insulated double wall pipe on February 25, 1987.

Observed heavy creosote buildup in the Security system, less creosote buildup with the James A. Ryder system.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W02

HOME TYPE: Newer Single Family Tract
Two Story

FLOOR AREA: 204 square meters
(2200 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 7 - 8

WOODSTOVE LOCATION: Basement Family Room

CHIMNEY SYSTEM DESCRIPTION:

18 cm (7 inches) single wall from flue collar to insulated cleanout tee (0.8 meters [2.6 feet])

18 cm by 23 cm (7 inches by 9 inches) packed pipe from cleanout tee to exit (5.2 meters [17.1 feet] within walls of house, 0.9 meters [3.0 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: RSF "65"

AGE: 5 years

FIREBOX VOLUME: 0.1348 cubic meters
(4.76 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Nu-Tec Catalytic Retrofit

TECHNOLOGY TYPE: Catalytic "Add-On" Retrofit

FIREBOX VOLUME: N/A

PARTICIPANT COMMENTS

Participant could not detect any change in heat output or fuel consumption resulting from the installation of the catalytic retrofit.
Participant feels that the Nu-Tec caused more rapid creosote buildup.
Smoke spillage occurred from stove door when loading stove, from unit housing at low burn.
Participant was alarmed by the catalyst temperature - up to 525° C (975° F).
Smoke spillage was the primary factor in the decision to remove the catalytic retrofit.
Liquid creosote dripped from cleanout tee when "seasoned" fuel was burned.

GENERAL COMMENTS

Nu-Tec catalytic retrofit installed January 15, 1987. Smoke spillage problem observed immediately after installation. Attempted to alleviate problem by eliminating a horizontal run in the chimney (February 9, 1987) and experimentation with an outside source of primary air for the woodstove.

Nu-Tec catalytic retrofit removed February 25, 1987.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W03

HOME TYPE:	Newer Single Family Custom Two Story	FLOOR AREA:	297 square meters (3200 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 6

WOODSTOVE LOCATION: Basement Family Room

CHIMNEY SYSTEM DESCRIPTION:

Stage 1: 20 cm (8 inches) single wall from flue collar to wall thimble (1.5 meters [4.9 feet])

Stage 2: 15 cm (6 inches) single wall from flue collar to wall thimble (1.5 meters [4.9 feet])

20 cm by 25 cm (8 inches by 10 inches) packed pipe from wall thimble to exit (5.3 meters [17.4 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: Fisher "Grandma Bear"

AGE:	4 years	FIREBOX VOLUME:	0.0997 cubic meters (3.52 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Burning Log "Turbo 10"

TECHNOLOGY TYPE:	Integral Catalytic	FIREBOX VOLUME:	0.0651 cubic meters (2.30 cubic feet)

PARTICIPANT COMMENTS

Had problems with smoke in home due to leaking connnections in the new 20 cm (6 inch) chimney. Connections refitted February 4, 1987.
Generally, participant felt that the stove was efficient with adequate heat output and burn times.
Stove did not provide enough heat output on one occasion when the outdoor temperature was -30°C (-22°F) and the house had cooled because the stove had been allowed to go out for chimney sweeping.
Participant felt that the relatively warm winter did not give the stove a chance to prove itself.

GENERAL COMMENTS

Burning Log "Turbo 10" and 15 cm (6 inch) single wall chimney from flue collar to wall thimble installed January 28, 1987.
Leaking connection 15 cm (6 inch) chimney repaired February 4, 1987.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W04

HOME TYPE: Newer Single Family Custom
Two Story

FLOOR AREA: 177 square meters
(1900 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 11

WOODSTOVE LOCATION: Basement Family Room

CHIMNEY SYSTEM DESCRIPTION:

15 cm (6 inch) single wall from flue collar to wall thimble (1.4 meters [4.6 feet])

15 cm by 20 cm (6 inches by 8 inches) packed pipe from wall thimble to exit (5.5 meters [18.0 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: Sears "Automatic"

AGE: 4 years

FIREBOX VOLUME: 0.0821 cubic meters
(2.90 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Osburn "Imperial 2000"

TECHNOLOGY TYPE: Low Emission Non-Catalytic

FIREBOX VOLUME: 0.0436 cubic meters
(1.54 cubic feet)

PARTICIPANT COMMENTS

Participant feels that heat output from the Osburn is adequate for warmer winter days, inadequate for colder days.

Stove will not burn overnight, maximum burn time four hours.

Even though the heat output was occasionally inadequate, home owner was surprised by the heating ability of the stove; originally the participant thought that the stove was too small.

Participant feels that "firekilled" fuel provides more heat output than "seasoned" fuel.

GENERAL COMMENTS

Osburn "Imperial 2000" installed January 16, 1987.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W05

HOME TYPE: Older Single Family Custom
Two Story(2600 square feet)

FLOOR AREA: 242 square meters

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 6

WOODSTOVE LOCATION: Basement Shop

CHIMNEY SYSTEM DESCRIPTION:

15 cm (6 inches) single wall from flue collar to wall thimble (1.5 meters [4.9 feet])

15 cm by 20 cm (6 inches by 8 inches) packed pipe from wall thimble to exit (5.0 meters [16.4 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: Acorn "Ranger"

AGE: 7 years

FIREBOX VOLUME: 0.1510 cubic meters
(5.33 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Uni-Com Catalytic Damper

TECHNOLOGY TYPE: Catalytic "Add-On" Retrofit

FIREBOX VOLUME: N/A

PARTICIPANT COMMENTS

Participant did not detect any improvement in stove performance after installation of the Uni-Com.
Smoke spillage usually occurred while loading the stove.
Installation of a smoke retainer flap did not improve the smoke spillage situation.
"Seasoned" fuel did not produce sufficient heat output; heat output was much lower than with "firekilled".

GENERAL COMMENTS

Uni-Com Catalytic Damper installed January 16, 1987.
Smoke retainer flap installed in stove March 12, 1987.
Participant removed Uni-Com at the conclusion of the study, primarily because of smoke spillage problems.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W06

HOME TYPE: Newer Single Family Custom Two Story

FLOOR AREA: 186 square meters (2000 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 5

WOODSTOVE LOCATION: Basement Family Room

CHIMNEY SYSTEM DESCRIPTION:

Stage 1: 20 cm (8 inches) single wall from flue collar to wall thimble (1.5 meters [4.9 feet])

Stage 2: 15 cm (6 inches) single wall from flue collar to wall thimble (1.5 meters [4.9 feet])

20 cm by 25 cm (8 inches by 10 inches) packed pipe from wall thimble to exit (5.4 meters [17.7 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: Energy King "Princess"

AGE: 5 years

FIREBOX VOLUME: 0.0906 cubic meters (3.20 cubic feet)

STAGE 2 - CONVENTIONAL TECHNOLOGY: Pacific Energy Systems "Super 27"

FIREBOX VOLUME: 0.0490 cubic meters (1.73 cubic feet)

PARTICIPANT COMMENTS

Participant feels that stove is adequate to -10°C (14°F), otherwise does not provide adequate heat output. Stove is also slow to heat house and does not burn overnight - 4 hours burn time at medium setting.

Some smoke spillage when loading fuel.

Insufficient room for ash/coalbed. Ashes spill when stove door is opened.

Fuel must be less than 30 cm (12 inches) long to be able to fill firebox.

Participant feels that fuel consumption was higher with the PES stove than with the Energy King stove.

GENERAL COMMENTS

Pacific Energy Systems "Super 27" installed January 16, 1987.

Draft control linkage broken March 1, 1987. Removed side convection shield from stove and operated draft control manually (without linkage) until linkage repaired March 20, 1987.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W07

HOME TYPE: Newer Single Family Custom Two Story

FLOOR AREA: 195 square meters (2100 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Electric Baseboard

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 7

WOODSTOVE LOCATION: Basement Family Room

CHIMNEY SYSTEM DESCRIPTION:

20 cm (8") single wall from flue collar to wall thimble (1.5 meters [4.9 feet])

20 cm by 25 cm (8" by 10") packed pipe from wall thimble to exit (5.2 meters [17.1 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: Blaze King "King" Non-Catalytic

AGE: 3 years

FIREBOX VOLUME: 0.1274 cubic meters (4.50 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Blaze King "King"

TECHNOLOGY TYPE: Integral Catalytic

FIREBOX VOLUME: 0.1221 cubic meters (4.31 cubic feet)

PARTICIPANT COMMENTS

Participant was very pleased with the performance of this stove.
Participant noted that it was hard to establish a good draft when lighting a fire with a cold chimney. Draft improved after the chimney was warm.
Fan made a "vibration-type" noise occasionally.
Participant feels that stove uses much less fuel than the conventional technology "King."
Catalytic "King" is more difficult to load because of the secondary air tubes in the firebox.

GENERAL COMMENTS

Blaze King "King" installed January 23, 1987.

Participant used outside source of primary combustion air on both conventional and new technology woodstoves.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W08

HOME TYPE: Newer Single Family Custom
Two Story

FLOOR AREA: 204 square meters
(2200 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 6 - 7

WOODSTOVE LOCATION: Unfinished Basement

CHIMNEY SYSTEM DESCRIPTION:

18 cm (7") single wall from flue collar to wall thimble (1.7 meters [5.6 feet])

18 cm by 23 cm (7" by 9") packed pipe from wall thimble to exit (5.5 meters [18.0 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: RSF "65"

AGE: 4 years

FIREBOX VOLUME: 0.1348 cubic meters
(4.76 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Uni-Com Catalytic Damper

TECHNOLOGY TYPE: Catalytic "Add-On" Retrofit

FIREBOX VOLUME: N/A

PARTICIPANT COMMENTS

Participant could not discern any change in stove performance after installation of catalytic retrofit.

Participant experienced smoke spillage while fueling stove. Smoke spillage seemed more severe when using "seasoned" fuel. Installation of a smoke retainer flap in the firebox significantly reduced smoke spillage.

GENERAL COMMENTS

Uni-Com Catalytic Damper installed January 20, 1987.
Smoke retainer flap installed February 9, 1987.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W09

HOME TYPE: Newer Single Family Custom Single Story

FLOOR AREA: 167 square meters (1800 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 7

WOODSTOVE LOCATION: Main Floor Living Room

CHIMNEY SYSTEM DESCRIPTION:

Initial: 20 cm by 25 cm (8" by 10") packed pipe from flue collar to ceiling thimble (1.5 meters [4.9 feet])

Final: 15 cm (6") single wall from flue collar to ceiling thimble (1.5 meters [4.9 feet])

20 cm by 25 cm (8" by 10") packed pipe from ceiling thimble to exit (0.9 meters [3.0 feet] in attic, 1.0 meters [3.3 feet] outside)—6 feet total

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: Energy King "King"

AGE: 4 years

FIREBOX VOLUME: 0.1274 cubic meters (4.50 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Osburn "Imperial 2000"

TECHNOLOGY TYPE: Low Emission Non-Catalytic

FIREBOX VOLUME: 0.0436 cubic meters (1.54 cubic feet)

PARTICIPANT COMMENTS

Participant feels that stove is inadequate in this application. Burn time is too short (5 hour burn maximum) and heat output is low.

Chimney change resulted in higher heat output, but heat output still insufficient.

GENERAL COMMENTS

Osburn "Imperial 2000" installed January 28, 1987.

Indoor portion of chimney system changed from 20 cm by 25 cm (8" by 10") packed pipe to 15 cm (6") single wall February 19, 1987.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W10

HOME TYPE: Newer Single Family Custom Two Story

FLOOR AREA: 174 square meters (1867 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 6

WOODSTOVE LOCATION: Unfinished Basement

CHIMNEY SYSTEM DESCRIPTION:

15 cm (6") single wall from flue collar to wall thimble (1.8 meters [5.9 feet])

15 cm by 20 cm (6" by 8") packed pipe from wall thimble to exit (3.0 meters [9.8 feet] within walls of house, 1.7 meters [5.6 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: Fisher "Mama Bear"

AGE: 5 years

FIREBOX VOLUME: 0.0773 cubic meters (273 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Double Wall Flue Pipe*

TECHNOLOGY TYPE: N/A

FIREBOX VOLUME: N/A

PARTICIPANT COMMENTS

Participant did not notice any change in stove performance with either of the double wall chimney systems.

GENERAL COMMENTS

*Used two different styles of double wall pipe during study.

Replaced the single wall with Security 15 cm (6") vented double wall pipe on February 3, 1987.

Replaced Security pipe with 15 cm (6") James A. Ryder air-insulated sealed double wall pipe on March 20, 1987.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W11

HOME TYPE: Newer Single Family Custom Two Story

FLOOR AREA: 204 square meters (2200 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood

SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 4

WOODSTOVE LOCATION: Unfinished Basement

CHIMNEY SYSTEM DESCRIPTION:

18 cm (7") single wall from flue collar to wall thimble (1.7 meters [5.6 feet])

18 cm by 23 cm (7" by 9") packed pipe from wall thimble to exit (5.3 meters [17.4 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: RSF "65"

AGE: 5 years

FIREBOX VOLUME: 0.1348 cubic meters (4.76 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Blaze King "King"

TECHNOLOGY TYPE: Integral Catalytic

FIREBOX VOLUME: 0.1221 cubic meters (4.31 cubic feet)

PARTICIPANT COMMENTS

Participant observed some smoke spillage when lighting a fire with the stove cold -- difficult to establish initial draft.

Participant pleased with the performance of the "King".

GENERAL COMMENTS

Blaze King "King" installed January 29, 1987.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W12

HOME TYPE:	Newer Single Family Custom Two Story	FLOOR AREA:	274 square meters (2950 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE:	Wood	SECONDARY HEAT SOURCE:	Electric Baseboard

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 6 1/2

WOODSTOVE LOCATION: Basement Family Room

CHIMNEY SYSTEM DESCRIPTION:

15 cm (6") single wall from flue collar to wall thimble (1.5 meters [4.9 feet])

15 cm by 20 cm (6" by 8") packed pipe from wall thimble to exit (4.7 meters [15.4 feet] framed in wood on outside wall of house, 0.8 meter [2.6 feet] outside), additional 0.8 meter (2.5 feet) added to top of chimney February 21, 1987.

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: Fisher "Papa Bear"

AGE:	7 years	FIREBOX VOLUME:	0.1039 cubic meter (3.67 cubic feet)

STAGE 2 - CONVENTIONAL TECHNOLOGY: Nu-Tec Catalytic Retrofit

TECHNOLOGY TYPE:	Catalytic "Add-On" Retrofit	FIREBOX VOLUME:	N/A

PARTICIPANT COMMENTS

Participant observed smoke spillage when lighting or fueling stove. Very difficult to establish draft when lighting the fire with a cold stove.

Participant could not detect any improvement in stove efficiency after installation of the Nu-Tec.

Home was filled with smoke on three occasions after installation of the Nu-Tec.

GENERAL COMMENTS

Nu-Tec Catalytic Retrofit installed February 5, 1987.

Home had a leaky chimney system which contributed to the incidents when smoke filled the home. Stove cement was used to help seal chimney after each chimney sweeping.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W13

HOME TYPE:	Mobile Home	FLOOR AREA:	70 square meters (750 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood	SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 6

WOODSTOVE LOCATION: Entrance Foyer Add-On to Mobile Home

CHIMNEY SYSTEM DESCRIPTION:

15 cm (6") single wall from flue collar to wall thimble (1.5 meters [4.9 feet])

15 cm by 20 cm (6" by 8") packed pipe from wall thimble to exit (0.9 meters [3.0 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: Search "Automatic"

AGE:	3 years	FIREBOX VOLUME:	0.0821 cubic meters (2.90 cubic feet)

STAGE 2 - CONVENTIONAL TECHNOLOGY: Pacific Energy Systems "Super 27"

FIREBOX VOLUME: 0.0490 cubic meters (1.73 cubic feet)

PARTICIPANT COMMENTS

PES "27" was installed facing the wrong direction. Participant would have preferred the stove to be rotated 90° from the current installation.

Participant did not like the 30 cm (12") fuel length requirement for the PES.

Participant was generally pleased with the overall performance of the new technology stove and felt that fuel consumption was lower than with the Sears stove.

GENERAL COMMENTS

Pacific Energy Systems "Super 27" installed January 20, 1987.

Participant widened doorway from entrance foyer to mobile home April 2, 1987; resulted in more heat transfer into mobile home.

WHITEHORSE EFFICIENT WOODHEAT DEMONSTRATION

Project Participant Profile

HOME CODE: W14

HOME TYPE:	Newer Single Family Custom Two Story	FLOOR AREA:	223 square meters (2400 square feet)

HEATING SYSTEM

PRIMARY HEAT SOURCE: Wood — SECONDARY HEAT SOURCE: Oil

ESTIMATED CORDS OF WOOD BURNED PER YEAR: 6

WOODSTOVE LOCATION: Basement Family Room

CHIMNEY SYSTEM DESCRIPTION:

18 cm (7") single wall from flue collar to cleanout tee (0.9 meters [3.0 feet])

20 cm (8") single wall from cleanout tee to ceiling thimble (0.8 meters [2.6 feet])

20 cm by 25 cm (8" by 10") packed pipe from wall thimble to exit (4.4 meters [14.4 feet] within walls of house, 0.6 meters [2.0 feet] outside)

STAGE 1 - CONVENTIONAL TECHNOLOGY WOODSTOVE: RSF "65"

AGE:	5 years	FIREBOX VOLUME:	0.1348 cubic meters (4.76 cubic feet)

STAGE 2 - NEW TECHNOLOGY: Burning Log "Turbo 10"

TECHNOLOGY TYPE:	Integral Catalytic	FIREBOX VOLUME:	0.0651 cubic meters (2.30 cubic feet)

PARTICIPANT COMMENTS

Participant felt that heat output of the Turbo 10 was adequate, however burn time was too short (8 hours maximum).

Observed creosote deposition on glass door on low burn setting, seasoned wood also caused increased creosote deposition on the glass door.

Participant plans on replacing the Turbo 10 with the RSF "65" at the conclusion of the study, primarily because of short burn times with the Turbo 10.

GENERAL COMMENTS

Burning Log "Turbo 10" installed February 5, 1987.